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**DIRECT-STRIKE LIGHTNING PHOTOGRAPHS,
SWEPT-FLASH ATTACHMENT PATTERNS,
AND FLIGHT CONDITIONS FOR
STORM HAZARDS '82**

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SUMMARY

As part of the NASA Langley Research Center Storm Hazards Program, 241 thunderstorm penetrations were made in 1982 with an F-106B airplane in order to record direct-strike lightning data and the associated flight conditions. During these penetrations, the airplane received 156 direct lightning strikes; in addition, lightning transient data were recorded from 26 nearby lightning flashes. The tests were conducted within 150 nautical miles of Hampton, Virginia, assisted by ground-based weather-radar guidance from the NASA Wallops Flight Facility.

This report presents the photographs of the lightning attachments taken from two onboard 16-mm color movie cameras and the associated strike attachment patterns. The paper also includes a table of the flight conditions recorded at the time of each lightning event, and a table in which the data in this paper are cross-referenced with the previously published lightning electromagnetic waveform data.

INTRODUCTION

The NASA Langley Research Center is performing in-flight direct-strike lightning research using a specially instrumented F-106B aircraft. The intent of this research is to refine the characterization of the lightning-generated electromagnetic environment affecting aircraft. The projected use of digital avionic systems, along with composite aircraft structure, compounds lightning-related problems and provides the motivation for the present research. Digital avionic systems are potentially more susceptible to upset by electrical transients than previous generation systems, and the composite structure may not provide electrical shielding equivalent to that provided by metal aircraft in the past. Future design processes will thus require lightning-protection assessment techniques for digital avionic systems operating in electromagnetically nonoptimum structures. A necessary requirement of potential assessment techniques (which may range from purely analytical, through simulation, to actual hardware tests) is a refined definition of the lightning electromagnetic hazards.

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This report presents the photographs of lightning attachments to the NASA F-106B thunderstorm research airplane taken from two onboard 16-mm color movie cameras during the 1982 program. The photographs are supplemented with the associated strike attachment patterns on the exterior of the airplane and the flight conditions recorded at the time of each direct strike and nearby flash. The lightning transient waveform data associated with the data presented in this paper were reported in reference 1. The transient data from the 1980 and 1981 programs were published in references 2 and 3, respectively. The corresponding lightning attachment patterns and flight conditions from 1980 and 1981 were reported in references 4 and 5 and the data from 1980 - 1982 were summarized in reference 6. A statistical analysis of the 1980 to 1982 lightning transient waveform data is reported in reference 7. Overviews of the Storm Hazards Program are given in references 8, 9, and 10.

TEST EQUIPMENT AND DATA REDUCTION

Test Equipment

F-106B research airplane. - A thoroughly instrumented F-106B "Delta Dart" airplane (figure 1) is used to make thunderstorm penetrations in the Storm Hazards Program. Details on the F-106B airplane and the criteria used in choosing the airplane for this mission can be found in references 4, 9, and 11. The lightning hardening procedures and verification tests undertaken prior to each thunderstorm season are described in references 9 and 11. Prior to the 1981 program, the paint was stripped from the top and bottom wing surfaces of the integral wing fuel tanks to reduce the lightning dwell times on those surfaces. This reduced the possibility of a melt-through of the aluminum skins covering the fuel cells.

Airborne lightning instrumentation system. - The direct-strike lightning instrumentation system (reference 7, 8, and 12) records the electromagnetic characteristics of direct lightning strikes and nearby lightning flashes. It consists of electromagnetic sensors mounted on the surface of the airplane, a shielded recording system in the weapons bay, and a control panel in the aft cockpit. Lightning transients were detected by four sensors whose outputs were recorded by the direct-strike lightning instrumentation system and by one additional sensor whose output was recorded on a Boeing Data Logger system mounted in the weapons bay (see ref. 13 and figure 1). The four measurements made in 1982 were (see figure 1):

\dot{D}_f -- Time-rate of change of electric flux density, D ; under the forward part of the airplane; measure by a flat-plate dipole antenna located under the nose of the airplane (see reference 14).

\dot{B}_L -- Time-rate of change of magnetic flux density, B , caused by longitudinal component (along fuselage) of current; measured by a multiple loop antenna on the right side of the fuselage above the wing (see reference 14).

i -- Time-rate of change of attachment current, I , to the nose boom by an inductive current probe located inside the fiberglass radome at the base of the metal nose boom. (see reference 14).

I -- Total attachment current, I , to the nose boom by current transformers located inside the radome. Outputs are recorded independently by NASA instrumentation and by the Boeing Data Logger system.

The recording system for the direct-strike lightning instrumentation system consisted of two digital transient recorders capable of recording 1.3 msec of data for each event at a 10-nsec sampling rate. Each transient recorder continually updated (recorded into) its memory until triggered, at which time the input was switched off until the memory content was serially dumped onto an analog magnetic tape recorder.

Airborne Cameras and Optics. - Two Milliken DBM-54 cameras were installed on the airplane to provide photographic coverage of the nose, tail, and left wing. A typical camera is shown in figure 2. The fields of view identifying fixed reference points for each camera are shown in figures 3 and 4. The frame rates of both were set to a minimum of 14 frames/sec to extend their data periods to 20 minutes. Even at the minimum frame rate, the cameras were turned on only during thunderstorm penetrations since each flight lasted approximately 60 minutes. Detailed information about camera and film characteristics is presented in table I. Time correlation with other instrumentation was obtained through an IRIG-B time-code modulated, light-emitting diode exposing the film edge.

The forward camera was installed in front of the cockpit to look forward through a periscope as shown in figures 1, 5, and 6. Because of space limitations, the camera was mounted on its side, as seen in figure 5. The forward camera field-of-view, shown in figure 3, includes the forward fuselage, radome, and nose boom with the angle-of-attack flow vane.

The aft-looking camera was installed at approximately mid-fuselage, above the left wing under a protective shroud, as shown in figures 1 and 7. The camera is shown mounted without the shroud in figure 8. Its field-of-view, shown in figure 4, exhibits the distortion that is characteristic of a wide-angle lens. However, this lens had to be a pin-hole lens because it was feared that the size of a normal wide-angle lens would interfere with the airflow around the fuselage. As was the case with the forward camera, the aft camera was mounted on its side because of limited space.

Other airborne data systems. - Environmental parameters and flight conditions were measured by the Aircraft Instrumentation System (AIS) and the Inertial Navigation System (INS). The descriptions of the lightning flashes by the flight crew were recorded on an onboard voice recorder which ran continuously without interruptions throughout the flight. The AIS and INS are described in references 4 and 6.

The fifteen airborne experiments conducted on the F-106B airplane between 1980 and 1982 are summarized in reference 6.

DATA REDUCTION

Determination of lightning attachment points. - When a lightning strike occurs to an aircraft, the lightning flash initially attaches to the aircraft at two or more locations called the initial lightning attachment points. As a minimum, there will be two attachment points consisting of a single entry point and a single exit point, as defined below. As described in reference 15, these points usually occur at extremities of the aircraft such as the nose or a wing tip. Since the aircraft flies more than its own length within the lifetime of most flashes, the lightning flash channel will reattach to other spots aft of the initial attachment points when the initial attachment points are at a forward portion of the aircraft. This occurrence is known as the swept-stroke phenomenon (refs. 15 and 16).

At any time, charge is flowing into one point of the airplane and out of another. No attempt has been made, using the attachment point analysis described in this paper, to determine the sign of that charge. Therefore, the use of the terms "entry" and "exit" in the definitions below are made without reference to direction of current flow and are arbitrarily chosen by physical location. The initial and final points are postulated based on data and previous experience. The definitions in common use in the lightning community to describe lightning attachment scenarios are:

lightning attachment point	Any spot where the lightning flash channel contacts the aircraft.
initial entry point	The first (in time) attachment point of a lightning flash channel where charges of one sign enter (flow onto) the aircraft. Arbitrarily chosen as a forward or upper location (usually an extremity).
final entry point	The last (in time) attachment point of the lightning flash channel where charges of one sign enter (flow onto) the aircraft (usually a trailing edge).
initial exit point	The first (in time) attachment point of a lightning flash channel where charges of the same sign as at the entry point leave (flow off) the aircraft. Arbitrarily chosen as an aft or lower location (usually an extremity). Coincident in time with the initial entry point.

final exit point

The last (in time) attachment point of a lightning flash channel where charges of the same sign as at the entry point leave (flow off) the aircraft (usually at a trailing edge). Coincident in time with the final entry point.

swept flash (or strike) points

intermediate spots where the lightning flash channel reattaches between its initial and final points.

These definitions are used in describing the scenarios presented in this paper, and also have been used to describe the scenarios postulated for the 1980 and 1981 data (refs. 4 and 5).

Following each flight in which there were direct lightning strikes, the lightning attachment points were located by careful inspection of the airplane surface. These attachment points along with films from the onboard cameras, sensor triggers, flight crew observations, and the procedure given in references 4 and 6, were used to postulate the initial and final attachment points, the swept-flash path(s), and the orientation of the channel.

Determining lightning images on movie film. - The frames selected for this report are those which show distinct lightning features. Included are many in which the image is distorted or partially obscured by rain, fog, or ice on the cover glass of the camera housing. Therefore, when these were severe enough to provide no visual information, the affected frames are not reprinted here, but are listed in the tables, and so marked.

A two-step process was used to identify those film frames associated with lightning strikes. First, the developed film was projected with a stepping-frame projector, and the sequences of interest were visually selected. Second, the film was reeled across a specially designed light table, and the time code was read from the film edge for correlation with data obtained by other instrumentation systems.

Determination of flight conditions. - Static temperature and pressure altitude were computed from parameters measured and recorded by the AIS. The pressure altitude was determined from static pressure values which were corrected for position error. The ambient temperature was determined from the total temperature measurement. The relative intensities of turbulence and precipitation at the times of the lightning strikes and nearby flashes were based on pilot observations as extracted from the cockpit voice transcripts.

DATA

The airplane flight conditions recorded during the direct strikes and nearby flashes that occurred in 1982 are summarized in table II. In table II, the lightning events are listed in chronological order along with the appropriate flight number, date (month and day), and time of occurrence (in coordinated universal time). The data entry for each lightning event also includes the pressure altitude, ambient temperature, true airspeed, pitch and bank attitude angles, and the location of the airplane with respect to the NASA Wallops Flight Facility at Wallops Island, Virginia. The airplane locations also are plotted on maps of the area in figure 9. Where there are clusters of points, each cluster is circled and the event numbers are listed adjacent to the circle.

The attachment point figures, lightning scenarios, and lightning photographs are presented in figures 10 through 170. Table III lists the figure numbers for the attachment point diagrams, scenario sketches, and direct-strike photographs presented in this paper along with the figure numbers of the associated lightning electromagnetic waveforms from reference 1. The photographs from each lightning event are arranged so that those from the forward camera precede those from the aft camera. Several photographic sequences showing lightning attachments also include frames that show no lightning activity; these frames were included to maintain the continuity of what seems to be the same event, such as a restrike along an established channel. Strike 16 (figure 50) is one such example.

During the 1982 thunderstorm season, 156 direct lightning strikes were positively identified. Of these, 77 strikes were filmed, and 131 were seen from the cockpit by the flight crew. There were sufficient coincidental data from the onboard systems to postulate 40 individual lightning attachment scenarios. As summarized in reference 6, four general categories of strike scenarios have been found in the lightning attachment point patterns from 1980 through 1982:

1. Flashes which initially enter the nose of the aircraft and subsequently "sweep" alongside it, reattaching at a succession of spots along the fuselage, as was the case with strike 16 of 1982 (see figures 20, 48, 49 and 50). In these cases, the initial and final exit points are usually the trailing edge of an extremity such as a wing or vertical fin tip. The final entry point is a trailing edge of the fuselage, because the flash is usually still alive by the time the aircraft has flown completely through it. The majority of the attachment patterns fell in this category.
2. Similar to (1) except that the entry channel sweeps aft across a top or bottom wing surface instead of the fuselage. An example of this pattern is that from strike 135 of 1982, shown in figures 126(c), 142, 143, and 144. Patterns from about 6 strikes have shown this pattern.

3. Strikes in which the initial entry and exit points occur at the nose. In this case, the lightning flash appears to "touch" the aircraft nose but continues on from this point to another destination. The aircraft then flies through the flash, resulting in successive entry points along one side of the fuselage or wing and exit points along the other. Again, because the flash usually exists for a longer time than it takes the aircraft to fly its length, the final entry and exit points are located along trailing edges. This scenario is illustrated by strike 63 of 1982, shown in figures 85, 89, 90, and 91. The only other examples in this category are strikes 2 and 3 of 1980 (See ref. 4.)
4. Strikes in which the initial and final entry and exit points are confined to the aft extremities, as shown in figures 20, 45, 46, and 47 (strike 15 of 1982). About one-third of the strikes to date have demonstrated this pattern.

With any of these general scenarios, it is possible for the swept flash channel to rejoin itself behind the airplane after the airplane has flown through the channel. In this case, the airplane becomes disconnected from the flash once the entry and exit portions of the channel have rejoined, thus allowing the airplane to fly out of the lightning flash. Photographs looking aft from the aircraft, such as figure 50 from strike 16, show that this occurred frequently. This result was unexpected, as previously it had been surmised that, once attached to the aircraft, the channel would remain attached until the flash died naturally.

The data from cameras, lightning sensors, and crew observations were not always sufficiently coincidental to permit postulating a scenario for every strike. Typically, the forward camera obtained much less data than the aft camera because strikes to the airplane remained attached to the trailing edges of the tail, fuselage, and wings for a longer period of time than the time the strikes would stay attached to the nose boom. All of the relatively few strikes captured by the forward camera were obscured to some degree by precipitation, condensation or frost on the periscope, and, therefore, contributed little information toward defining lightning structure or locating lightning attachments. Precipitation erosion or breakage of the cover glass was also a continual problem, although various glasses and plastics were tried. For example, a photograph for strike 24 of 1982 (figure 63) shows the cracked glass, which broke completely later during the flight. Consequently, the forward camera system was removed entirely from the F-106B airplane after flight 82-027 on July 11, 1982 (see table III). Although a number of aft camera events also were obscured by condensation and frost on the cover glass of the shroud, the majority of these pictures showed the lightning clearly. Finally, many of the crew calls contained no descriptive information on channel orientation or location.

The relative turbulence and precipitation intensities called by the flight crew during each lightning event in 1982 are tabulated in table IV. As summarized in ref. 6, most strikes and nearby flashes occurred in areas of the thunderstorms where the relative intensities of turbulence and precipitation were characterized as negligible.

SUMMARY OF DATA

During the NASA Langley Research Center Storm Hazards Program, 241 thunderstorm penetrations were made in 1982 with an F-106B airplane in order to record direct-strike lightning data and the associated flight conditions. The lightning attachment point data and lightning photographs may be summarized as follows:

1. Confirmed lightning events consisted of 156 direct lightning strikes and 26 nearby flashes. Lightning attachments were filmed successfully during 77 of these strikes.
2. There were sufficient coincidental airborne data to postulate 40 individual lightning attachment scenarios.
3. Four general categories of scenarios are recognizable in the lightning attachment point data. An additional characteristic is that, following several attachments, the channel was seen to rejoin itself behind the airplane after the airplane had flown through the channel.

REFERENCES

1. Thomas, Mitchel E.; and Pitts, Felix L.: 1982 Direct Strike Lightning Data. NASA TM-84626, Mar. 1983.
2. Pitts, Felix L.; and Thomas, Mitchel E.: 1980 Direct Strike Lightning Data. NASA TM-81946, Feb. 1981.
3. Pitts, Felix L.; and Thomas, Mitchel E.: 1981 Direct Strike Lightning Data. NASA TM-83273, Mar. 1982.
4. Fisher, Bruce D.; Keyser, Gerald L., Jr.; and Deal, Perry L.: Lightning Attachment Patterns and Flight Conditions for Storm Hazards '80. NASA TP-2087, Dec. 1982.
5. Fisher, Bruce D.: Lightning Swept-Stroke Attachment Patterns and Flight Conditions for Storm Hazards '81. NASA TM 86279, Aug. 1984.
6. Fisher, Bruce D.; and Plumer, J. Anderson: Lightning Attachment Patterns and Flight Conditions Experienced by the NASA F-106B Airplane. Procs. Addendum. Eighth Inter. Aero. and Ground Conf. on Lightning and Static Elec., Ft. Worth, TX, June 1983. DOT/FAA/CT-83/15(A), pp. 26-1 - 26-14.
7. Lee, L. D.; Finelli, G. B.; Thomas, M. E.; and Pitts, F. L.: Statistical Analysis of Direct Strike Lightning Data (1980 to 1982). NASA TP 2252, Jan. 1984.
8. Pitts, Felix L.: Electromagnetic Measurement of Lightning Strikes to Aircraft. J. Aircraft, Vol. 19, No. 3, Mar. 1982, pp. 246-250. (Available as AIAA 81-0083R.)
9. Deal, Perry L.; Keyser, Gerald L.; Fisher, Bruce D.; and Crabill, Norman L.: Thunderstorm Hazards Flight Research - Program Overview. AIAA-81-2412, Nov. 1981.
10. Neely, Maj. William., Jr.; and Fisher, Bruce D.: The NASA F-106B Storm Hazards Program. Procs., Twenty-Sixth Annual Symp., Soc. of Exper. Test Pilots, Los Angeles, CA, Sept. 1983, pp. 242-256.
11. Fisher, Bruce D.; Keyser, Gerald L., Jr.; Deal, Perry L.; Thomas, Mitchel E.; and Pitts, Felix L.: Storm Hazards '79 - F-106B Operations Summary. NASA TM-81779, Mar. 1980.
12. Thomas, M. E.: Direct Strike Lightning Measurement System. AIAA-81-2513, Nov. 1981.
13. von Bokern, Greg J.: In-Flight Lightning Data Measurement System for Fleet Application-Flight Test Results. Proc., National Aero. and Elec. Conf., Dayton, OH, Vol. 1, May 1982, pp. 25-31.

14. Trost, Thomas F.; and Zaepfel, Klaus P.: Broadband Electromagnetic Sensors for Aircraft Lightning Research. Lightning Technology, NASA CP-2128, FAA-RD-80-30, 1980, pp. 131-152.
15. Fisher, Franklin A.; and Plumer, J. Anderson: Lightning Protection of Aircraft. NASA RP-1008, 1977.
16. SAE Committee AE4L: Lightning Test Waveforms and Techniques for Aerospace Vehicles and Hardware. Soc. Automot. Eng., Inc., June 20, 1978.

TABLE II.- AIRPLANE FLIGHT CONDITIONS DURING DIRECT STRIKES AND NEARBY FLASHES IN 1982

EVENT	FLIGHT #2-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG (a)	BANK ANGLE DEG (b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 1	010	MAY 23	21: 2:31.0	6117	20069	-14	220	427	2	5	-173	-187
STRIKE 2	010	MAY 23	21:25: 1.0	6134	20123	-15	208	404	2	-8	-101	-218
STRIKE 3	010	MAY 23	21:36:35.0	6223	20416	-15	213	414	5	-15	-86	-209
STRIKE 4	013	MAY 28	20:13:45.0	8625	24790	-35	229	445	3	9	77	-99
STRIKE 5	013	MAY 28	20:48:58.0	8625	28296	-35	224	435	4	1	105	-89
STRIKE 6	013	MAY 28	20:49:10.0	8590	28183	-36	231	449	4	1	105	-92
STRIKE 7	013	MAY 28	20:54:52.0	8771	28777	-35	234	454	3	12	110	-108
STRIKE 8	013	MAY 28	20:55:11.0	8581	28154	-32	238	462	4	-1	106	-105
STRIKE 9	017	JUNE 05	18:10:22.0	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)
STRIKE 10	017	JUNE 05	18:11:39.4	7640	25065	-28	239	464	3	6	-239	33
STRIKE 11	017	JUNE 05	18:23:48.0	7681	25199	-26	223	433	1	-2	-237	-3
STRIKE 12	017	JUNE 05	18:24: .5	7658	25123	-26	231	449	2	-10	-239	-5
STRIKE 13	017	JUNE 05	18:28:34.0	7673	25172	-31	251	487	0	-1	-235	-1
STRIKE 14	017	JUNE 05	18:28:50.0	7675	25180	-29	245	476	3	8	-232	3
STRIKE 15	017	JUNE 05	18:35:27.8	7651	25102	-27	234	454	2	4	-233	-1
STRIKE 16	017	JUNE 05	18:39:45.8	7638	25058	-31	237	460	3	3	-227	4
STRIKE 17	017	JUNE 05	18:47: 3.0	7676	25185	-28	230	447	-1	-1	-241	0
STRIKE 18	020	JUNE 17	19: 8:15.0	7749	25422	-22	214	415	2	31	-127	-29
STRIKE 19	020	JUNE 17	19:30:45.0	7678	25189	-24	225	437	4	0	-115	-4
NEARBY 1	020	JUNE 17	19:31: 3.0	7727	25350	-27	238	462	4	38	-116	-8

TABLE II.- Continued.

EVENT	FLIGHT RP-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, °C	TRUE AIRSPEED		PITCH ANGLE DEG(a)	BANK ANGLE DEG(b)	DISTANCE FROM NASA WFF, KM(c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
NEARBY 2	021	JUNE 21	20: 4:37.0	7780	25553	-23	207	402	6	10	-202	3
NEARBY 3	021	JUNE 21	20: 7: .0	7780	25526	-27	216	419	0	7	-189	-12
NEARBY 4	021	JUNE 21	20: 7: 9.0	7630	25034	-25	224	435	5	-9	-187	-12
NEARBY 5	021	JUNE 21	20:22:27.0	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)
NEARBY 6	021	JUNE 21	20:22:52.0	6340	20790	-14	219	425	6	3	-188	9
NEARBY 7	021	JUNE 21	20:23:12.0	6332	20774	-13	213	414	2	0	-185	6
NEARBY 8	021	JUNE 21	20:23:26.0	6215	20389	-14	226	439	4	6	-183	4
STRIKE 20	023	JUNE 29	20:47:21.0	8613	28257	-28	232	450	4	-3	-204	-8
STRIKE 21	023	JUNE 29	20:47:30.0	8639	28345	-30	233	452	0	5	-204	-10
STRIKE 22	023	JUNE 29	20:48:30.0	8613	28256	-28	237	460	3	-6	-206	-23
STRIKE 23	023	JUNE 29	20:53:51.3	8666	28433	-31	243	472	4	23	-205	-36
STRIKE 24	023	JUNE 29	20:54:29.7	8572	28124	-28	251	487	5	14	-205	-36
STRIKE 25	023	JUNE 29	20:54:35.0	8672	28450	-26	227	441	5	-1	-209	-26
STRIKE 26	023	JUNE 29	20:59:39.6	8691	28514	-31	252	489	3	-12	-195	7
STRIKE 27	023	JUNE 29	21: 6:45.2	8616	28269	-30	244	474	1	-3	-199	8
NEARBY 9	024	JULY 04	20:18:26.0	10701	35107	-49	273	530	2	-1	-140	-315
NEARBY 10	024	JULY 04	20:22:41.0	10773	35346	-43	275	534	1	-9	-144	-312
STRIKE 28	024	JULY 04	20:22:56.0	10604	34791	-39	265	515	3	1	-144	-312
NEARBY 11	024	JULY 04	20:24: 2.0	10650	34942	-39	270	524	5	-9	-150	-293
STRIKE 29	024	JULY 04	20:29:18.0	10607	34800	-40	286	555	2	3	-146	-308
STRIKE 30	024	JULY 04	20:34:33.0	10724	35182	-38	268	520	5	1	-146	-304

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG (a)	BANK ANGLE DEG (b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 31	024	JULY 04	20:35:20.0	10584	34725	-40	284	552	3	6	-152	-291
STRIKE 32	024	JULY 04	20:42:23.0	10461	34322	-42	290	563	6	-2	-158	-306
STRIKE 33	024	JULY 04	20:42:29.0	10625	34858	-40	283	550	5	-6	-152	-307
STRIKE 34	024	JULY 04	20:42:35.0	10675	35023	-40	284	552	1	-3	-157	-309
STRIKE 35	024	JULY 04	20:55:56.0	10625	34858	-43	283	550	4	-5	-160	-299
STRIKE 36	024	JULY 04	20:56:28.0	10472	34357	-42	282	548	0	-2	-156	-307
STRIKE 37	024	JULY 04	20:56:31.7	10542	34588	-42	283	550	3	11	-156	-307
STRIKE 38	024	JULY 04	20:56:36.0	10582	34719	-41	280	544	2	-5	-155	-308
NEARBY 12	024	JULY 04	20:56:56.0	10346	33945	-43	286	555	4	2	-153	-313
NEARBY 13	024	JULY 04	21: 2: 5.0	10708	35132	-38	271	526	2	-3	-160	-306
STRIKE 39	024	JULY 04	21: 2:11.0	10671	35009	-40	271	526	1	1	-161	-306
STRIKE 40	024	JULY 04	21: 2:47.0	10526	34535	-40	268	520	3	-12	-169	-298
STRIKE 41	024	JULY 04	21: 3: 3.0	10593	34753	-42	270	524	3	-3	-172	-294
STRIKE 42	026	JULY 10	21: 8:50.0	7801	25595	-26	233	452	0	0	-53	-114
STRIKE 43	026	JULY 10	21:13:12.0	7600	24935	-26	230	447	2	1	-89	-131
STRIKE 44	026	JULY 10	21:21:24.0	7645	25083	-26	233	452	1	-23	-40	-113
STRIKE 45	027	JULY 11	18: 8:41.0	7570	25163	-26	233	452	3	-1	-52	-161
STRIKE 46	027	JULY 11	19:10:22.0	7397	24208	-17	226	439	6	1	-91	-91
NEARBY 14	027	JULY 11	19:14: .0	7426	24354	-18	231	449	3	-5	-92	-90
STRIKE 47	028	JULY 11	22:53:34.0	7698	25257	-27	237	460	0	-4	-36	-257
STRIKE 48	028	JULY 11	23: 0:10.0	7605	24955	-30	243	472	3	-49	-25	-233

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG(a)	BANK ANGLE DEG(b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 49	028	JULY 11	23: 6:45.0	7679	25192	-28	232	450	4	-1	-18	-234
STRIKE 50	028	JULY 11	23: 6:45.0	7679	25192	-28	232	450	4	-1	-18	-234
STRIKE 51	028	JULY 11	23:17:25.0	7673	25173	-30	245	476	1	-14	-31	-238
STRIKE 52	028	JULY 11	23:25:32.0	7638	25060	-28	228	443	3	4	-54	-267
STRIKE 53	028	JULY 11	23:25:35.0	7667	25155	-29	231	449	5	3	-39	-242
STRIKE 54	028	JULY 11	23:32: 7.0	7667	25155	-29	231	449	5	3	-39	-242
NEARBY 15	028	JULY 11	23:38:35.0	7694	25243	-28	226	439	4	5	-38	-238
STRIKE 55	028	JULY 11	23:47:43.0	7862	25794	-25	222	431	-1	-9	-45	-246
NEARBY 16	029	JULY 16	20:10: .0	7661	25135	-21	229	445	7	1	75	-3
STRIKE 56	029	JULY 16	20:10:27.0	7649	25094	-19	234	454	2	-5	81	-4
STRIKE 57	030	JULY 17	19:36:55.0	7770	25494	-26	246	478	1	2	-147	-65
STRIKE 58	030	JULY 17	19:58:56.0	9309	30541	-34	252	489	2	2	-138	-72
STRIKE 59	030	JULY 17	20: 6:10.0	9325	30594	-34	258	501	6	1	-135	-70
STRIKE 60	032	JULY 28	18:23:49.0	8822	28943	-30	251	487	3	-2	135	-86
STRIKE 61	033	JULY 28	22:26:48.0	8789	28836	-32	255	495	3	2	-53	-115
STRIKE 62	034	JULY 30	19:30:24.0	7629	25028	-29	231	449	4	2	107	-40
STRIKE 63	034	JULY 30	19:30:34.0	7644	25079	-31	239	464	4	5	106	-41
STRIKE 64	034	JULY 30	19:30:34.0	7644	25079	-31	239	464	4	5	106	-41
STRIKE 65	034	JULY 30	19:49: 3.0	6761	22184	-24	220	427	6	11	107	-19
STRIKE 66	034	JULY 30	19:55:30.0	6744	22127	-19	217	421	4	-15	106	-27
STRIKE 67	034	JULY 30	20:11:20.0	6094	19995	-11	207	402	5	36	108	0

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG(a)	BANK ANGLE DEG(b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 68	035	JULY 31	19:49:10.0	5511	18081	-5	210	408	5	-25	-96	-87
NEARBY 17	035	JULY 31	20: 2:19.0	7018	23024	-15	223	433	3	-10	-119	-30
NEARBY 18	037	AUG 06	19:50: 5.0	8811	28909	-34	254	493	3	-1	16	-110
NEARBY 19	037	AUG 06	19:50: 8.0	8815	28922	-35	258	501	6	0	16	-110
STRIKE 69	037	AUG 06	20: 5:11.0	11030	36188	-48	262	509	5	-1	13	-59
STRIKE 70	037	AUG 06	20: 5:24.0	11077	36342	-49	261	507	4	-3	12	-62
NEARBY 20	037	AUG 06	20:30:28.0	8592	28188	-35	257	499	7	-1	3	-60
STRIKE 71	038	AUG 08	20:12:21.0	9433	30948	-40	255	495	3	3	-163	-33
STRIKE 72	038	AUG 08	20:12:21.0	9433	30948	-40	255	495	3	3	-163	-33
STRIKE 73	038	AUG 08	20:12:28.0	9421	30908	-39	254	493	7	0	-163	-34
STRIKE 74	038	AUG 08	20:12:37.0	9476	31090	-39	253	491	6	3	-162	-36
STRIKE 75	038	AUG 08	20:13:44.0	9490	31136	-36	246	478	6	0	-155	-51
STRIKE 76	038	AUG 08	20:13:54.0	9521	31237	-38	247	480	3	2	-154	-54
STRIKE 77	038	AUG 08	20:18: 5.0	9669	31723	-40	244	474	7	0	-148	-61
STRIKE 78	038	AUG 08	20:32: 2.0	9741	31959	-37	243	472	2	0	-163	-137
NEARBY 21	038	AUG 08	20:43:27.0	6564	21537	-21	211	410	3	-48	-172	-130
STRIKE 79	039	AUG 09	19:48:39.0	6478	21254	-13	211	410	5	0	-41	-86
STRIKE 80	039	AUG 09	20: 6:56.0	8246	27053	-28	243	472	4	-5	-22	-58
STRIKE 81	040	AUG 09	22:29:40.0	9359	30705	-37	243	472	4	0	-84	-152
NEARBY 22	040	AUG 09	22:33:39.0	9330	30611	-33	231	449	1	4	-45	-103
NEARBY 23	040	AUG 09	22:34:44.0	9267	30402	-33	241	468	7	2	-31	-93

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG (a)	BANK ANGLE DEG (b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 82	040	AUG 09	22:34:48.0	9287	30468	-34	242	470	6	-8	-30	-93
STRIKE 83	040	AUG 09	22:34:55.0	9361	30713	-33	238	462	6	5	-29	-92
STRIKE 84	040	AUG 09	22:41:53.0	9435	30955	-34	248	482	3	1	-40	-96
STRIKE 85	040	AUG 09	22:43:42.0	9479	31099	-39	242	470	0	-5	-59	-113
STRIKE 86	040	AUG 09	22:45:20.0	9460	31038	-39	251	487	6	1	-78	-127
STRIKE 87	040	AUG 09	22:52:58.0	9430	30939	-44	266	517	3	-16	-45	-100
STRIKE 88	040	AUG 09	23: 3:14.0	9440	30971	-39	254	493	3	7	-48	-99
STRIKE 89	040	AUG 09	23: 3:52.0	9457	31028	-39	252	489	6	3	-57	-102
STRIKE 90	040	AUG 09	23: 8:42.0	9485	31120	-36	236	458	3	-33	-93	-153
STRIKE 91	041	AUG 11	16:17:31.0	7661	25133	-26	242	470	4	3	-36	-129
STRIKE 92	041	AUG 11	16:23:36.0	8890	29161	-30	231	449	5	9	-42	-127
STRIKE 93	041	AUG 11	16:23:54.0	9093	29833	-33	240	466	-1	2	-43	-131
STRIKE 94	041	AUG 11	16:29:55.0	8777	28794	-35	237	460	6	-5	-38	-134
NEARBY 24	041	AUG 11	16:31:14.0	8879	29132	-37	244	474	7	-1	-35	-113
STRIKE 95	041	AUG 11	16:31:42.0	8775	28789	-41	261	507	4	-5	-33	-106
STRIKE 96	041	AUG 11	16:32: .0	8859	29064	-41	260	505	2	11	-32	-101
STRIKE 97	041	AUG 11	16:37:15.0	8799	28869	-35	243	472	4	-1	-39	-99
STRIKE 98	041	AUG 11	16:38:39.0	9003	29538	-30	240	466	-1	-11	-39	-118
STRIKE 99	041	AUG 11	16:38:45.0	8966	29417	-33	248	482	-1	-5	-39	-120
NEARBY 25	041	AUG 11	16:39:16.0	8927	29286	-36	252	489	4	-33	-40	-127
STRIKE 100	041	AUG 11	16:43:10.0	8840	29003	-33	212	412	-1	-55	-50	-129

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG (a)	BANK ANGLE DEG (b)	DISTANCE FROM NASA WFF, KM (c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 101	041	AUG 11	16:44:23.0	8863	29079	-29	224	435	3	-7	-39	-116
STRIKE 102	041	AUG 11	16:45: 4.0	8724	28621	-29	215	417	0	-9	-35	-106
STRIKE 103	041	AUG 11	16:45:10.0	8746	28694	-29	216	419	1	-4	-35	-105
STRIKE 104	041	AUG 11	16:45:59.0	8743	28683	-31	228	443	6	12	-34	-91
STRIKE 105	041	AUG 11	16:51:34.0	8218	26963	-30	232	450	3	1	-33	-81
STRIKE 106	041	AUG 11	16:51:39.0	8254	27079	-32	234	454	2	2	-33	-82
STRIKE 107	041	AUG 11	16:51:47.0	8283	27175	-33	238	462	-2	2	-33	-84
STRIKE 108	041	AUG 11	16:51:53.0	8241	27037	-34	243	472	-2	-3	-34	-85
STRIKE 109	041	AUG 11	16:53:34.0	8152	26744	-31	240	466	2	-6	-39	-110
STRIKE 110	041	AUG 11	16:53:34.0	8152	26744	-31	240	466	2	-6	-39	-110
STRIKE 111	041	AUG 11	16:54: 3.0	8220	26969	-35	246	478	0	26	-40	-116
STRIKE 112	041	AUG 11	17: 0:23.0	8193	26879	-37	247	480	3	-12	-35	-102
STRIKE 113	042	AUG 11	22: 1:48.0	8830	28971	-37	239	464	2	-2	-194	-187
STRIKE 114	042	AUG 11	22: 1:55.0	8857	29058	-38	246	478	2	-1	-193	-185
STRIKE 115	042	AUG 11	22: 2: .0	8884	29147	-40	254	493	4	4	-192	-184
STRIKE 116	042	AUG 11	22: 8:34.0	8245	27050	-32	241	468	2	1	-186	-157
STRIKE 117	042	AUG 11	22: 8:43.0	8249	27063	-31	242	470	1	5	-186	-157
STRIKE 118	042	AUG 11	22:12:12.0	8192	26877	-35	242	470	3	1	-209	-195
NEARBY 26	042	AUG 11	22:13:10.0	8289	27195	-32	240	466	2	-9	-221	-202
STRIKE 119	042	AUG 11	22:18: 1.0	8203	26913	-34	247	480	5	-2	-219	-197
STRIKE 120	042	AUG 11	22:18:38.5	8226	26989	-34	248	482	3	8	-210	-191

TABLE II.- Continued.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE ALTITUDE		AMBIENT TEMPERATURE, C	TRUE AIRSPEED		PITCH ANGLE DEG(a)	BANK ANGLE DEG(b)	DISTANCE FROM NASA WFF, KM(c)	
				M	FT		M/SEC	KNOTS			NORTH	EAST
STRIKE 121	042	AUG 11	22:20:42.0	8190	26873	-33	238	462	5	5	-185	-170
STRIKE 122	043	AUG 17	20: 0:54.0	9076	29778	-42	250	465	1	-5	-86	-149
STRIKE 123	043	AUG 17	20:22:45.0	8505	27904	-29	240	466	3	4	-73	-116
STRIKE 124	043	AUG 17	20:25:18.0	8650	28380	-29	232	450	2	2	-70	-82
STRIKE 125	043	AUG 17	20:25:26.0	8536	28332	-31	238	462	3	11	-71	-81
STRIKE 126	044	AUG 25	20:30:13.0	10494	34429	-43	256	497	4	0	-124	26
STRIKE 127	044	AUG 25	20:31:21.0	10448	34277	-45	262	509	4	5	-108	36
STRIKE 128	044	AUG 25	20:31:40.0	10415	34170	-42	253	491	0	-3	-104	40
STRIKE 129	044	AUG 25	20:37:37.2	10284	33740	-44	255	495	6	2	-98	55
STRIKE 130	044	AUG 25	20:38:10.0	10332	33897	-42	258	501	5	4	-103	49
STRIKE 131	044	AUG 25	20:38:30.0	10406	34142	-45	256	497	6	0	-107	45
STRIKE 132	044	AUG 25	20:39: 8.0	10413	34164	-48	267	519	5	-1	-114	39
STRIKE 133	044	AUG 25	20:39:32.0	10437	34243	-49	273	530	8	-5	-118	35
STRIKE 134	044	AUG 25	20:46:11.0	10393	34097	-39	278	540	-2	6	-120	42
STRIKE 135	044	AUG 25	20:46:25.0	10329	33887	-41	283	550	3	-4	-117	45
STRIKE 136	044	AUG 25	20:47:20.0	10434	34232	-48	273	530	3	-7	-105	56
STRIKE 137	044	AUG 25	20:47:30.0	10454	34298	-46	264	513	3	-2	-103	57
STRIKE 138	044	AUG 25	20:55:35.0	10452	34292	-43	253	491	5	-5	-110	57
STRIKE 139	044	AUG 25	20:55:51.0	10419	34183	-44	252	489	5	3	-113	54
STRIKE 140	044	AUG 25	21: 2:45.0	11053	36262	-39	267	519	5	-2	-126	28
STRIKE 141	044	AUG 25	21: 3: 6.0	10938	35885	-37	259	503	5	38	-122	32

TABLE II.- Concluded.

EVENT	FLIGHT 82-	DATE	TIME GMT	PRESSURE		ALTITUDE FT	AMBIENT TEMPERATURE,C	TRUE	AIRSPEED	PITCH ANGLE DEG(a)	BANK ANGLE DEG(b)	DISTANCE FROM NASA WFF, KM (c)	
				M				M/SEC	KNOTS			NORTH	EAST
STRIKE 142	044	AUG 25	21:15: 2.0	10789		35397	-49	256	497	7	-5	-119	60
STRIKE 143	044	AUG 25	21:15:35.0	11113		36461	-46	257	499	-1	-4	-124	54
STRIKE 144	044	AUG 25	21:16:38.0	11057		36277	-47	276	536	2	3	-132	40
STRIKE 145	044	AUG 25	21:16:42.0	11220		36412	-46	263	511	-1	6	-133	39
STRIKE 146	044	AUG 25	21:20:33.0	9963		32687	-42	267	519	1	1	-131	40
STRIKE 147	044	AUG 25	21:20:42.0	10017		32865	-39	272	528	1	22	-130	42
STRIKE 148	044	AUG 25	21:20:32.5	9699		31820	-41	259	503	4	-3	-130	47
STRIKE 149	047	SEPT 20	15:53: 5.5	6730		22080	-26	229	445	2	-10	-156	43
STRIKE 150	047	SEPT 20	16: 5:13.0	4645		15240	-4	194	377	3	3	-132	88
STRIKE 151	048	SEPT 20	21: 2:44.0	9386		30795	-37	247	480	2	4	-238	-125
STRIKE 152	048	SEPT 20	21: 2:59.4	9352		30682	-35	250	485	4	5	-237	-121
STRIKE 153	048	SEPT 20	21: 4:22.7	9314		30558	-41	245	476	3	-7	-221	-109
STRIKE 154	048	SEPT 20	21:12:50.0	9379		30770	-36	231	449	1	37	-175	-19
STRIKE 155	048	SEPT 20	21:21: 4.6	9267		30403	-36	254	493	4	14	-232	-105
STRIKE 156	048	SEPT 20	21:21: 5.8	9267		30404	-35	250	485	6	11	-232	-106

- Notes: (a) Positive for nose up.
 (b) Positive for right wing down.
 (c) Positive for North and East.
 (d) Data not available.

TABLE I. - CAMERA AND FILM CHARACTERISTICS

Camera type, forward and aft	Milliken DBM-54
Frame rate, each camera, frames/sec	14
Shutter speed, forward camera, millisecc	14
Shutter speed, aft camera, millisecc	39
Shutter opening, forward camera, degrees	72
Shutter opening, aft camera, degrees	200
f-stop, forward camera	22 ^(a)
f-stop, aft camera	57
Focal length, forward camera, mm	15
Focal length, aft camera, mm	5.1
Film speed, ASA	64
Film length, m	122
Film type	Ektachrome 7256

Note (a): f-16 during Flight 82-010

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario	Camera		Fwd.	Aft.	D _f	B _L	i	l	Boeing l
					Fwd.	Aft.							
STRIKE 1	010	May 23	10	11	-	12	0	2 (iv)	1	-	-	-	-
2	↓	↓	10, 13	14	15	16	1	3	2	-	2	-	-
3	↓	↓	10, 17	18	-	19	0	2	3	-	-	-	-
4	013	May 28	20, 21	22	-	23	0	10 (iv)	1	-	-	-	-
5	↓	↓	-	-	-	-	0	0	-	-	-	2	-
6	↓	↓	-	-	-	-	0	0	3	-	-	3	-
7	↓	↓	-	-	-	-	0	0	-	-	-	4	-
8	↓	↓	-	-	-	-	0	0	-	-	-	5	-
9	017	June 5	20, 24	25	-	26	0	9	-	-	-	-	-
10	↓	↓	20, 27	28	29	30	1	3	-	-	-	-	-
11	↓	↓	20, 31	32	-	33	0	3	-	-	-	2	-
12	↓	↓	20, 34	35	-	36	0	2	-	-	-	-	-
13	↓	↓	20, 37	38	39	40	1	7	-	-	-	3	-
14	↓	↓	20, 41	42	43	44	1	8	-	-	-	-	-
15	↓	↓	20, 45	46	-	47	0	3	-	-	-	-	-
16	↓	↓	20, 48	49	-	50	0	10	-	-	-	-	-
17	↓	↓	20	-	-	-	0	0	2	-	-	4	-
18	020	June 17	51, 52	53	-	54	0	2	1	-	-	-	-
19	↓	↓	51, 55	56	-	-	0	0	2	-	-	-	-
NEARBY 1	↓	↓	-	-	-	-	0	0	3	-	-	-	-
2	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-
3	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-
4	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-
5	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-
6	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario	Camera		Fwd.	Aft.	\dot{D}_f	\dot{B}_L	i	I	Boeing I
					Fwd.	Aft.							
NEARBY 7	021	June 21	-	-	-	-	0	0	(i)	-	-	-	-
8	↓	↓	-	-	-	-	0	0	(i)	-	-	-	-
STRIKE 20	023	June 29	-	-	57	58	1	2	1	-	-	-	-
21			-	-	59	60	1	2	-	-	2	-	-
22			-	-	-	61	0	1	3	-	-	-	-
23			-	-	-	62	0	2	-	-	-	-	-
24			-	-	63	64	1	1	-	-	-	-	-
25			-	-	-	65	0	2	-	-	-	-	-
26			-	-	(v)	66	10 (v)	5	-	-	-	-	-
27	↓	↓	-	-	(v)	67	10 (v)	10	-	-	-	-	-
NEARBY 9	024	July 4	-	-	(ii)	-	(ii)	0	1	-	-	-	-
10			-	-		-		0	2	-	-	-	-
STRIKE 28			-	-		(v)		2 (v)	3	-	-	-	-
NEARBY 11			-	-		-		0	4	-	-	-	-
STRIKE 29			-	-		-		0	5	-	-	-	-
30			-	-		(v)		3 (v)	6	-	-	-	-
31			-	-		68		1	7	-	-	7	-
32			-	-		-		0	8	-	-	-	-
33			-	-		-		0	9	-	-	-	-
34			-	-		-		0	10	-	-	-	-
35			-	-		69		4	11	-	-	-	-
36			-	-		70		1	12	-	-	-	-
37			-	-		71		1	-	-	-	-	-
38			-	-		72		1	13	-	-	-	-
NEARBY 12	↓	↓	-	-	↓	-	↓	0	14	-	-	-	-

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario	Camera		Fwd.	Aft.	\dot{D}_f	\dot{B}_L	\dot{i}	\dot{l}	Boeing
NEARBY 13	024	July 4	-	-	(ii)	-	(ii)	0	15	-	-	-	-
STRIKE 39			-	-		-		0	16	-	-	-	-
40			-	-		-		0	17	-	-	-	-
41	↓	↓	-	-	↓	-	↓	0	18	-	-	-	-
42	026	July 10	73	-	-	-	0	0	1	-	-	-	-
43	↓	↓	73	-	-	-	0	0	2	-	-	-	2
44	↓	↓	73	-	-	-	0	0	3	-	-	-	-
45	027	July 11	73	-	-	74	0	4	1	-	-	-	-
46			73	-	-	-	0	0	2	-	-	-	-
NEARBY 14	↓		-	-	-	-	0	0	3	-	-	-	-
STRIKE 47	028		73, 75	76	(iii)	77	(iii)	3	1	-	-	-	-
48			73, 78	79		80		10 (iv)	2	-	-	-	-
49			73, 81	82		83		7	3	-	-	-	-
50			73	-		-		0	-	-	-	-	-
51			73	-		-		0	4	-	-	-	-
52			73	-		-		0	5	-	-	-	-
53			73	-		-		0	-	-	-	-	-
54			73	-	↓	-		0	6	-	-	-	6
NEARBY 15			-	-	-	-		0	7	-	-	-	-
STRIKE 55	↓	↓	73	-	(iii)	-		0	8	-	-	-	-
NEARBY 16	029	July 16	-	-		-		0	1	-	-	-	-
STRIKE 56	↓	↓	-	-		-		0	2	-	-	-	-
57	030	July 17	-	-		-		0	1	-	-	-	-
58	↓	↓	-	-		-		0	2	-	-	-	-
59	↓	↓	-	-	↓	84	↓	4	3	-	-	-	-

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-		Camera		No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario			Fwd.	Aft.	D _f	B _L	i	l	Boeing
					Fwd.	Aft.							l
Strike 60	032	July 28	-	-	-	-	0	0	1	-	-	-	-
61	033	↓	-	-	(iii)	(ii)	(iii)	(ii)	2	2	-	-	-
62	034	July 30	85, 86	87		88		5	1	-	-	-	-
63			85, 89	90		91		3	2	-	-	-	-
64			85	-		-		0	-	-	-	-	-
65			85, 92	93		94		10	3	-	-	-	-
66			85	-		-		0	4	-	-	-	-
67	↓	↓	85	-		-		0	5	-	-	-	-
68	035	July 31	85	-		(ii)		(ii)	1	-	-	-	-
Nearby 17	↓	↓	-	-		↓		(ii)	2	-	-	-	-
18	037	August 6	-	-		-		0	1	-	-	-	-
19			-	-		-		0	-	1	-	-	-
Strike 69			95	-		-		0	2	2	-	-	-
70			95, 96	97		98		3	3	3	-	-	-
Nearby 20	↓	↓	-	-		-		0	4	4	-	-	-
Strike 71	038	August 8	95, 99	100		101		13	(i)	1	-	-	-
72			95	-		-		0	-	-	-	-	-
73			95	-		-		0	2	2	-	-	-
74			95, 102	103		104		9	-	3	-	-	-
75			95, 105	106		107		5	4	4	-	-	-
76			95	-		108		2	5	5	-	-	-
77			95, 109	110		111		5	6	-	-	-	-
78			95	-		-		0	7	7	-	-	-
Nearby 21	↓	↓	-	-		-		0	8	8	-	-	-
Strike 79	039	August 9	112, 113	114	↓	115	↓	3	1	1	-	-	(iii)

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-					
			Attach. pts.	Scenario	Camera				D _f	B _L	i	l	Boeing	
					Fwd.	Aft.	Fwd.	Aft.					l	
Strike 80	039	August 9	112, 116	117	(iii)	118	(iii)	4	2	2	-	-	(iii)	
81	040	August 9	112, 119	120		121		5	1	1	-	-	-	
Nearby 22			-	-		-		0	-	2	-	-	-	
23			-	-		-		0	-	3	-	-	-	
Strike 82			112, 122	123		124		5	3	-	-	-	-	
83			112	-		125		1	4	4	-	-	-	
84			112	-		-		0	-	5	-	-	-	
85			112	-		-		0	6	6	-	-	-	
86			112	-		-		0	7	7	-	-	-	
87			112	-		-		0	-	8	-	-	-	
88			112	-		-		0	-	-	-	-	-	
89			112	-		-		0	-	-	-	-	-	
90	↓	↓	112	-		-		0	-	-	-	-	-	
91	041	August 11	-	-		(ii)		(ii)	-	1	-	-	-	
92			-	-					2	2	-	-	-	
93			-	-					3	-	-	-	-	
94			-	-					4	4	-	-	-	
Nearby 24			-	-					-	5	-	-	-	
Strike 95			-	-					6	6	-	-	6	
96			-	-					-	-	-	-	-	
97			-	-					7	7	-	-	-	
98			-	-					8	8	-	-	7	
99			-	-					9	i	-	-	-	
Nearby 25			-	-					10	10	-	-	-	
Strike 100	↓	↓	-	-		↓	↓	↓	↓	11	11	-	-	-

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario	Camera		Fwd.	Aft.	D _f	B _L	i	l	Boeing
					Fwd.	Aft.							l
Strike 101	041	August 11	-	-	(iii)	(ii)	(iii)	(ii)	12	12	-	-	-
102			-	-					13	13	-	-	-
103			-	-					14	14	-	-	-
104			-	-					15	15	-	-	-
105			-	-					-	-	-	-	-
106			-	-					16	16	-	-	-
107			-	-					17	17	-	-	-
108			-	-					-	-	-	-	-
109			-	-					18	18	-	-	18
110			-	-					-	-	-	-	-
111			-	-					19	19	-	-	-
112	↓	↓	-	-		↓		↓	20	20	-	-	20
113	042	August 11	-	-		-		0	1	1	-	-	-
114			-	-		-		0	2	2	-	-	-
115			-	-		-		0	-	-	-	-	-
116			-	-		(vi)		4 (vi)	3	3	-	-	-
117			-	-		(vi)		2 (vi)	4	4	-	-	-
118			-	-		(vi)		4 (vi)	5	5	-	-	5
Nearby 26			-	-		-		0	6	6	-	-	-
Strike 119			-	-		(vi)		5 (vi)	7	7	-	-	-
120			-	-		-		0	8	8	-	-	-
121	↓	↓	-	-		-		0	9	9	-	-	-
122	043	August 17	-	-		(vi)		3 (vi)	-	-	1	1	(iii)
123			-	-		-		0	-	-	-	-	
124	↓	↓	-	-	↓	(vi)	↓	3 (vi)	-	-	-	-	

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

Event	Flight 82-	Date	Figure nos. for-				No. of camera frames		Run no. from ref. 1 for-				
			Attach. pts.	Scenario	Camera		Fwd.	Aft.	D _f	B _L	i	l	Boeing l
					Fwd.	Aft.							
Strike 125	043	August 17	-	-	(iii)	(vi)	(iii)	1 (vi)	-	-	2	2	(iii)
126	044	August 25	126, 127	128		129		5	-	-	-	-	-
127			126	-		130		3	-	-	-	-	-
128			126, 131	132		133		2	-	-	-	-	-
129			126	-		-		0	-	-	1	1	-
130			126, 134	135		136		4	-	-	-	-	-
131			126, 137	138		139		2	-	-	-	-	-
132			126	-		140		2	-	-	2	2	2
133			126	-		-		0	-	-	-	-	-
134			126	-		141		1	-	-	-	-	-
135			126, 142	143		144		2	-	-	-	-	-
136			126, 145	146		147		4	-	-	-	-	-
137			126, 148	149		150		4	-	-	3	3	-
138			126	-		151		3	-	-	-	-	-
139			126, 152	153		154		5	-	-	-	-	-
140			126	-		155		1	-	-	-	-	-
141			126	-		-		0	-	-	4	4	4
142			126	-		-		0	-	-	-	-	-
143			126	-		156		2	-	-	-	-	-
144			126	-		-		0	-	-	-	-	-
145			126	-		157		1	-	-	-	-	-
146			126	-		158		5	-	-	-	-	-
147			126	-		-		0	-	-	-	-	-
148	↓	↓	126	-		159		3(vii)	-	-	-	-	-
149	047	Sept. 20	-	-	↓	-	↓	0	-	-	1	1	-

TABLE III - 1982 LIGHTNING DATA CROSS-REFERENCE TABLE

[illegible]

Key for Table III

- (i) Waveform not usable.
- (ii) Inoperative.
- (iii) Not installed.
- (iv) One frame with no distinct structure is omitted.
- (v) All frames omitted. No distinct structure.
- (vi) All frames omitted. Lens iced over.
- (vii) Two frames omitted. Lens iced over.

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 1	010	Negligible	Negligible
STRIKE 2	↓	↓	↓
STRIKE 3	↓	↓	↓
STRIKE 4	013	↓	Light
STRIKE 5	↓	↓	Negligible
STRIKE 6	↓	↓	Light
STRIKE 7	↓	↓	Negligible
STRIKE 8	↓	Heavy	
STRIKE 9	017	Negligible	
STRIKE 10	↓	↓	
STRIKE 11	↓	↓	
STRIKE 12	↓	↓	
STRIKE 13	↓	↓	
STRIKE 14	↓	↓	
STRIKE 15	↓	↓	
STRIKE 16	↓	Light	
STRIKE 17	↓	Negligible	
STRIKE 18	020	↓	
STRIKE 19	↓	↓	
NEARBY 1	↓	↓	
NEARBY 2	021	↓	
NEARBY 3	↓	↓	
NEARBY 4	↓	↓	
NEARBY 5	↓	↓	
NEARBY 6	↓	↓	
NEARBY 7	↓	↓	
NEARBY 8	↓	↓	↓
STRIKE 20	023	↓	Moderate
STRIKE 21		Light	Negligible

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 22	023	Negligible	Heavy
STRIKE 23			Negligible
STRIKE 24			Heavy
STRIKE 25			Negligible
STRIKE 26		↓	↓
STRIKE 27	↓	Light	Light
NEARBY 9	024	↓	Negligible
NEARBY 10		Moderate	
STRIKE 28		↓	
NEARBY 11		Negligible	
STRIKE 29		Heavy	
STRIKE 30		↓	
STRIKE 31		Negligible	↓
STRIKE 32		Light	Light
STRIKE 33		↓	Negligible
STRIKE 34		↓	
STRIKE 35		Negligible	
STRIKE 36		Heavy	
STRIKE 37		↓	
STRIKE 38		↓	
NEARBY 12		Negligible	
NEARBY 13			
STRIKE 39			
STRIKE 40			
STRIKE 41	↓	↓	↓
STRIKE 42	026	Heavy	Moderate
STRIKE 43		Negligible	Negligible
STRIKE 44	↓	Negligible	Negligible
STRIKE 45	027	Light	

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 46	027	Heavy	Heavy
NEARBY 14	↓	↓	Moderate
STRIKE 47	028	↓	Negligible
STRIKE 48	↓	Negligible	↓
STRIKE 49	↓	↓	↓
STRIKE 50	↓	↓	↓
STRIKE 51	↓	↓	↓
STRIKE 52	↓	↓	Moderate
STRIKE 53	↓	↓	↓
STRIKE 54	↓	↓	↓
NEARBY 15	↓	Light	↓
STRIKE 55	↓	Negligible	Heavy
NEARBY 16	029	↓	Moderate
STRIKE 56	↓	↓	Negligible
STRIKE 57	030	Light	Moderate
STRIKE 58	↓	↓	Light
STRIKE 59	↓	↓	Moderate
STRIKE 60	032	Heavy	Heavy
STRIKE 61	033	Negligible	↓
STRIKE 62	034	↓	Negligible
STRIKE 63	↓	↓	↓
STRIKE 64	↓	↓	↓
STRIKE 65	↓	↓	↓
STRIKE 66	↓	↓	↓
STRIKE 67	↓	↓	↓
STRIKE 68	035	↓	↓
NEARBY 17	↓	Negligible	Moderate
NEARBY 18	037	Light	↓
NEARBY 19	↓	↓	↓

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 69	037	Negligible	Negligible
STRIKE 70	↓		
NEARBY 20	↓		
STRIKE 71	038		
STRIKE 72			
STRIKE 73			
STRIKE 74			↓
STRIKE 75			Moderate
STRIKE 76			↓
STRIKE 77		↓	Light
STRIKE 78		Moderate	Moderate
NEARBY 21		Negligible	↓
STRIKE 79			Negligible
STRIKE 80	↓	↓	
STRIKE 81	040	Light	
NEARBY 22		Negligible	
NEARBY 23			
STRIKE 82			
STRIKE 83			
STRIKE 84			
STRIKE 85			
STRIKE 86			
STRIKE 87			
STRIKE 88			
STRIKE 89			
STRIKE 90	↓	↓	
STRIKE 91	041	Light	
STRIKE 92	↓	Moderate	
STRIKE 93	↓	Negligible	↓

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 94	041	Negligible	Heavy
NEARBY 24			Moderate
STRIKE 95			Negligible
STRIKE 96			
STRIKE 97		↓	
STRIKE 98		Light	
STRIKE 99		↓	
NEARBY 25		Negligible	↓
STRIKE 100			Moderate
STRIKE 101			Negligible
STRIKE 102			
STRIKE 103			
STRIKE 104		↓	
STRIKE 105		Moderate	
STRIKE 106		↓	
STRIKE 107		↓	↓
STRIKE 108		Negligible	Heavy
STRIKE 109			Negligible
STRIKE 110			
STRIKE 111			
STRIKE 112	↓		
STRIKE 113	042		
STRIKE 114			
STRIKE 115		↓	↓
STRIKE 116		Light	Moderate
STRIKE 117		↓	↓
STRIKE 118		Negligible	Negligible
NEARBY 26	↓	↓	Light
STRIKE 119		Light	↓

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

Event	Flight 82-	Relative precipitation intensity	Relative turbulence intensity
STRIKE 120	042	Light	Heavy
STRIKE 121	↓	↓	Negligible
STRIKE 122	043	↓	Heavy
STRIKE 123	↓	Negligible	Negligible
STRIKE 124	↓	↓	Moderate
STRIKE 125	↓	↓	Moderate
STRIKE 126	044	↓	Negligible
STRIKE 127		Light	
STRIKE 128		Negligible	
STRIKE 129			
STRIKE 130			
STRIKE 131			
STRIKE 132			
STRIKE 133			
STRIKE 134			
STRIKE 135			
STRIKE 136			
STRIKE 137			
STRIKE 138			
STRIKE 139			
STRIKE 140			
STRIKE 141			
STRIKE 142			
STRIKE 143			
STRIKE 144			
STRIKE 145			
STRIKE 146			
STRIKE 147			
STRIKE 148	↓	↓	↓

TABLE IV - RELATIVE PRECIPITATION AND TURBULENCE INTENSITIES
DURING LIGHTNING EVENTS IN 1982

[illegible]

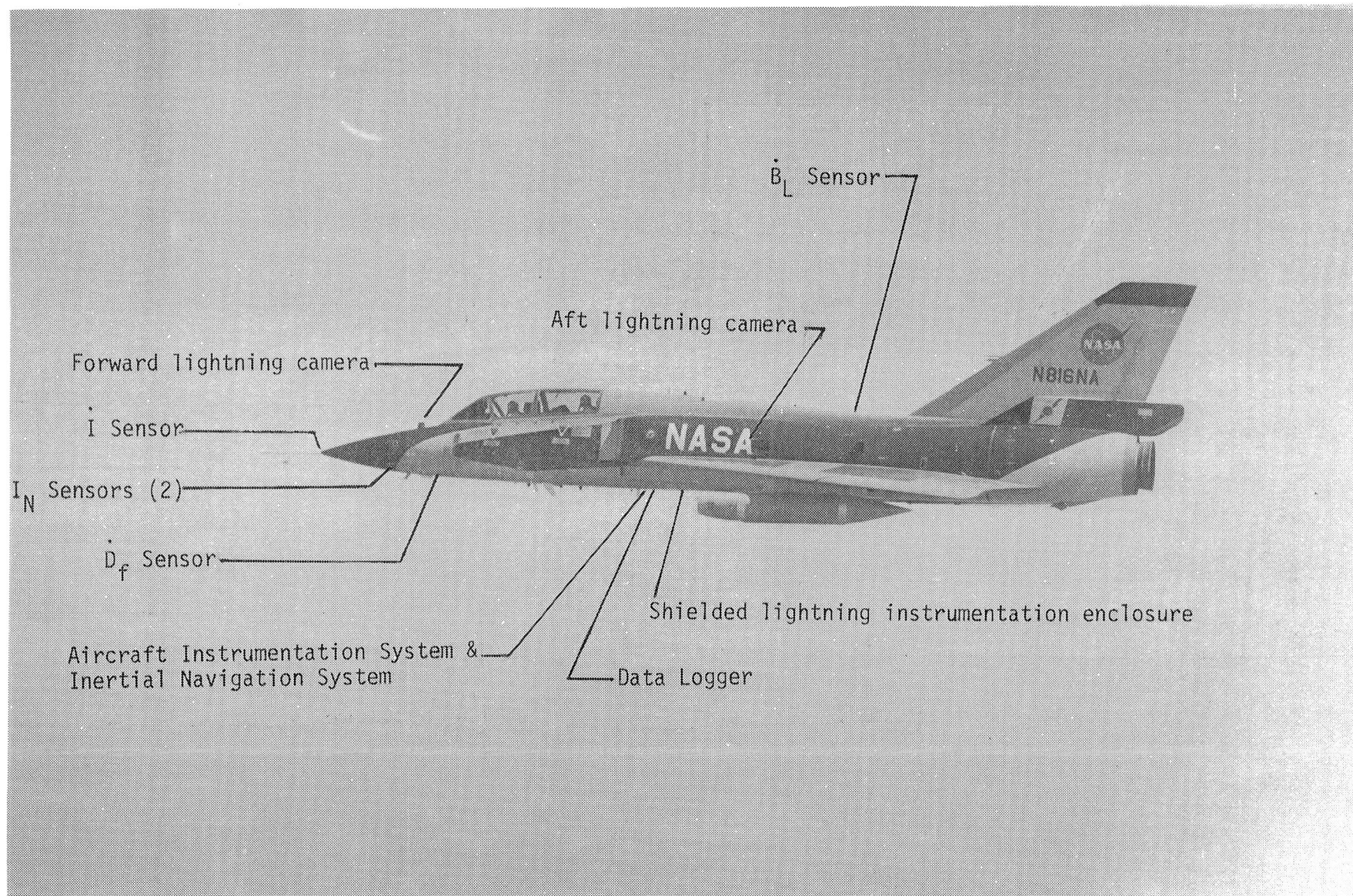


Figure 1.- NASA Langley Research Center Storm Hazards '82 research vehicle.

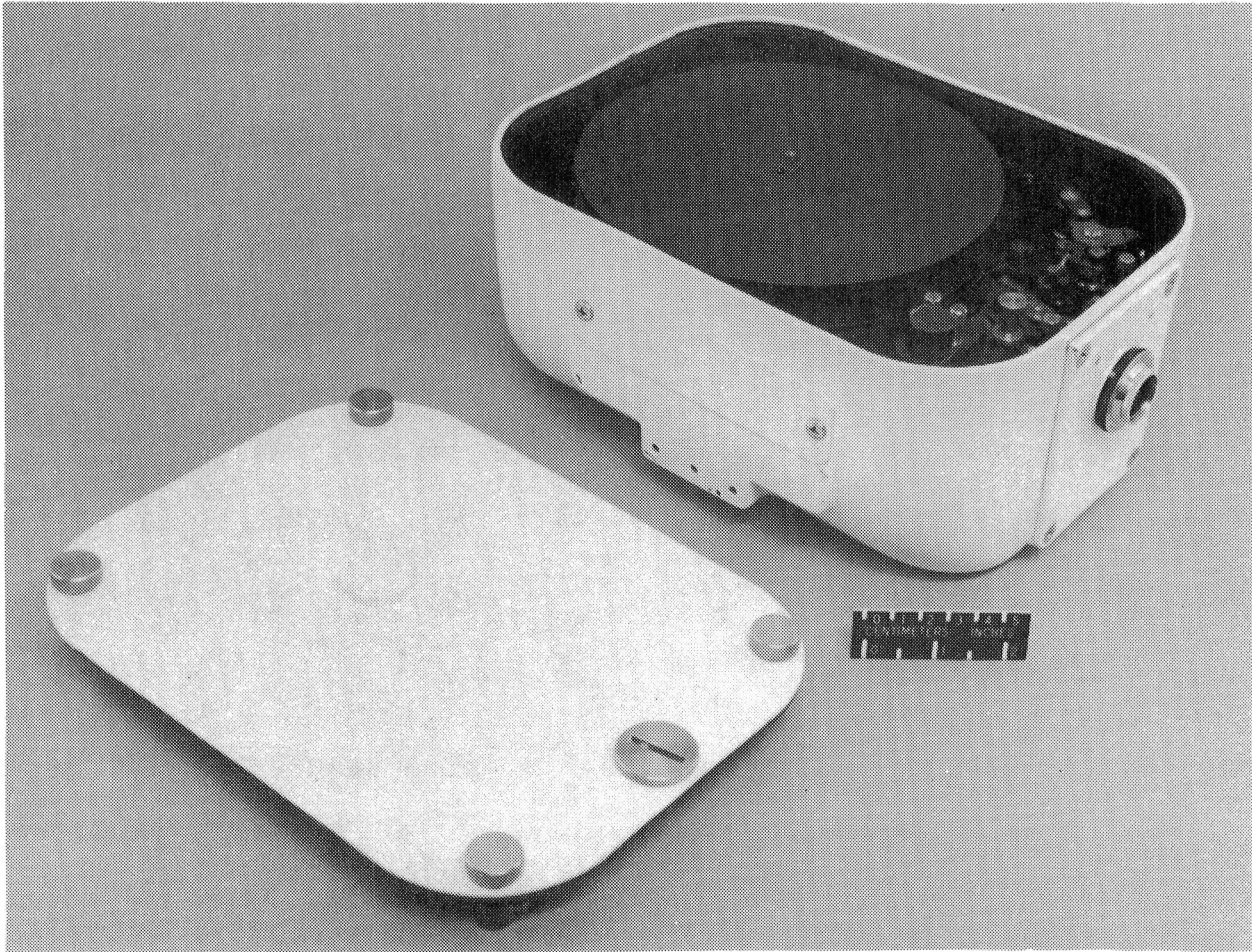


Figure 2. - Milliken Model DBM-54 Camera.

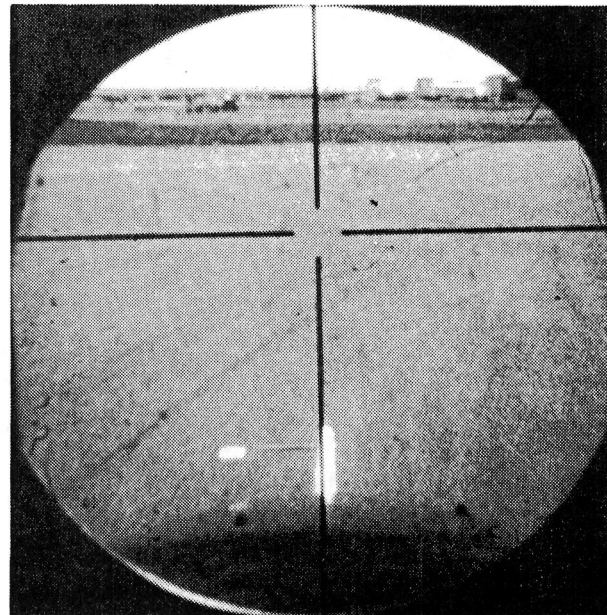
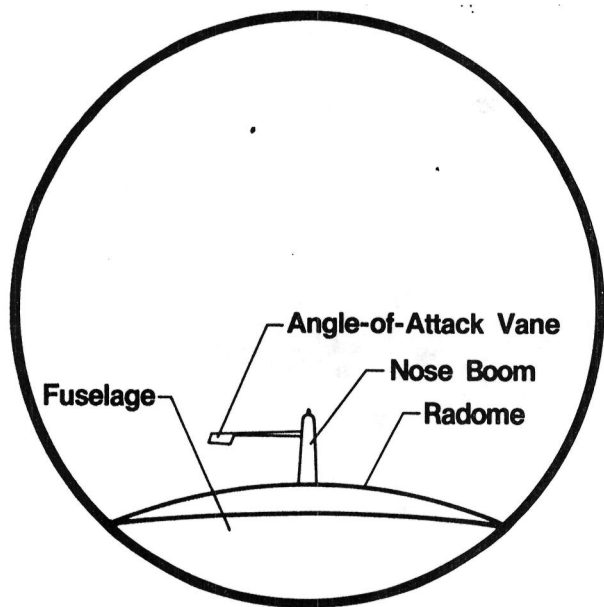


Figure 3. - Field of view of the forward camera.

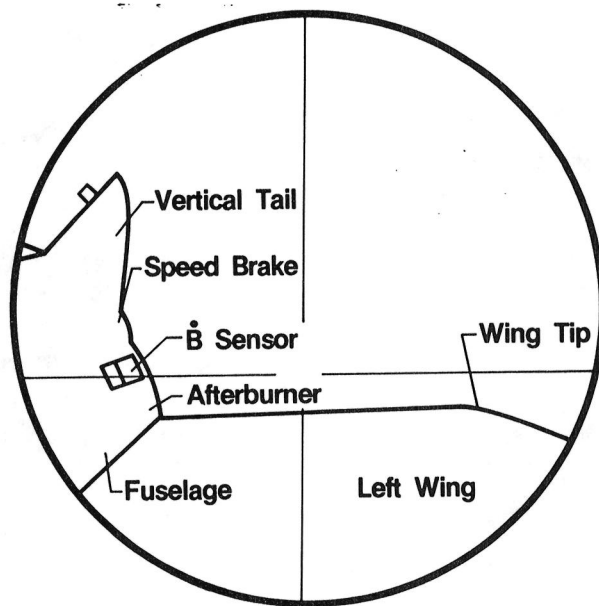


Figure 4. - Field of view of the aft camera.

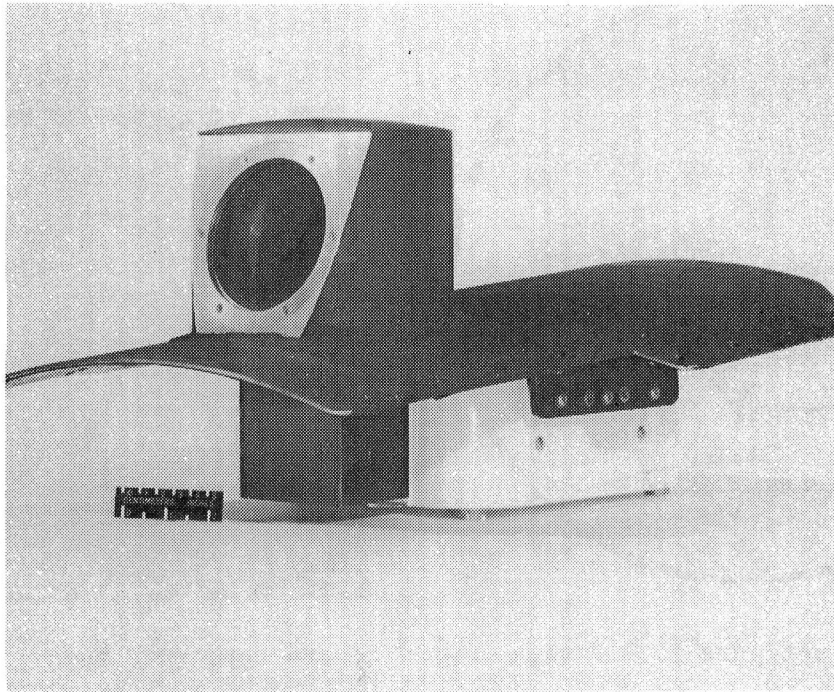


Figure 5. - Forward camera and periscope

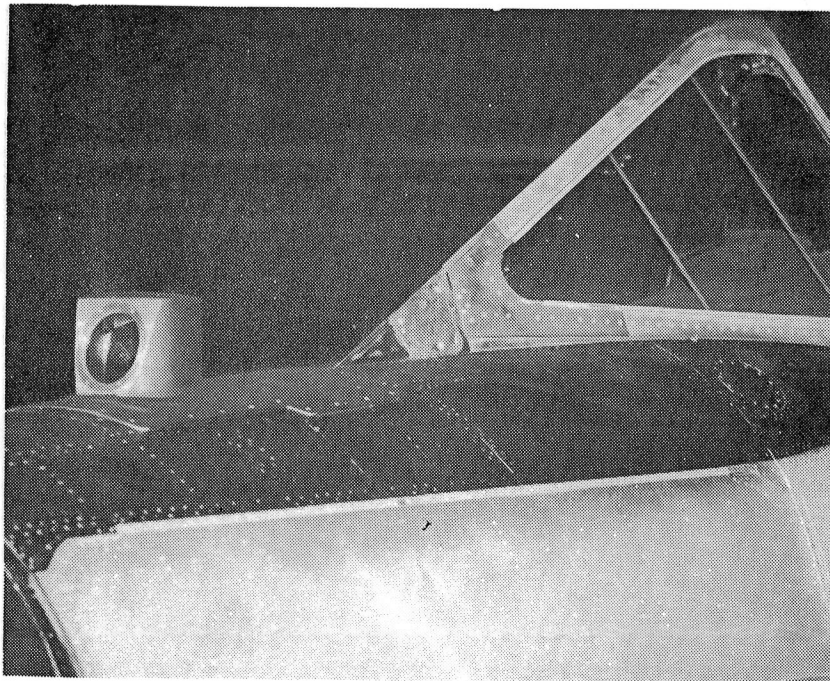


Figure 6. - Forward camera system installed on F-106B.

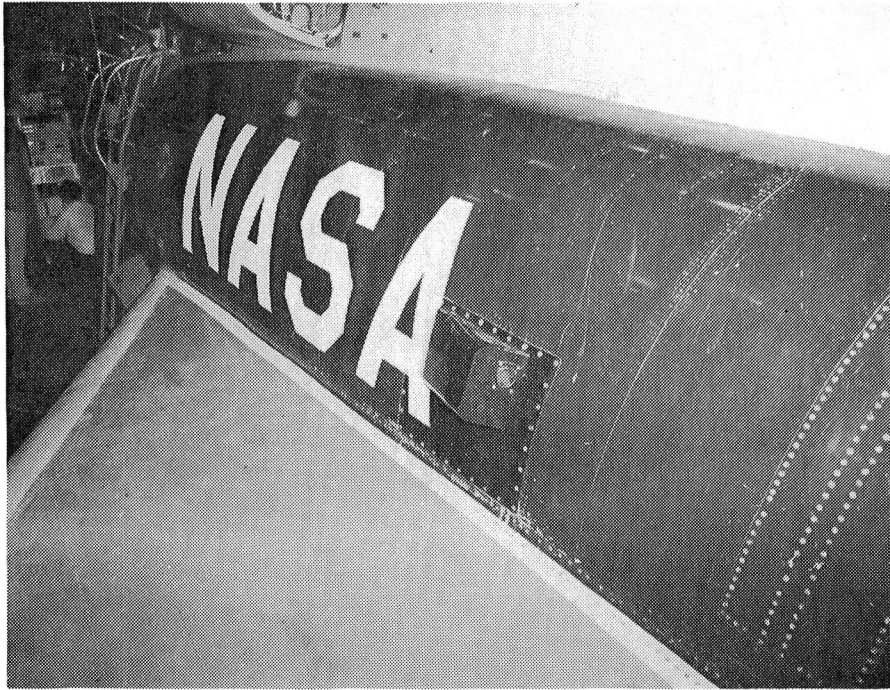


Figure 7. - Aft camera under shroud on F-106B

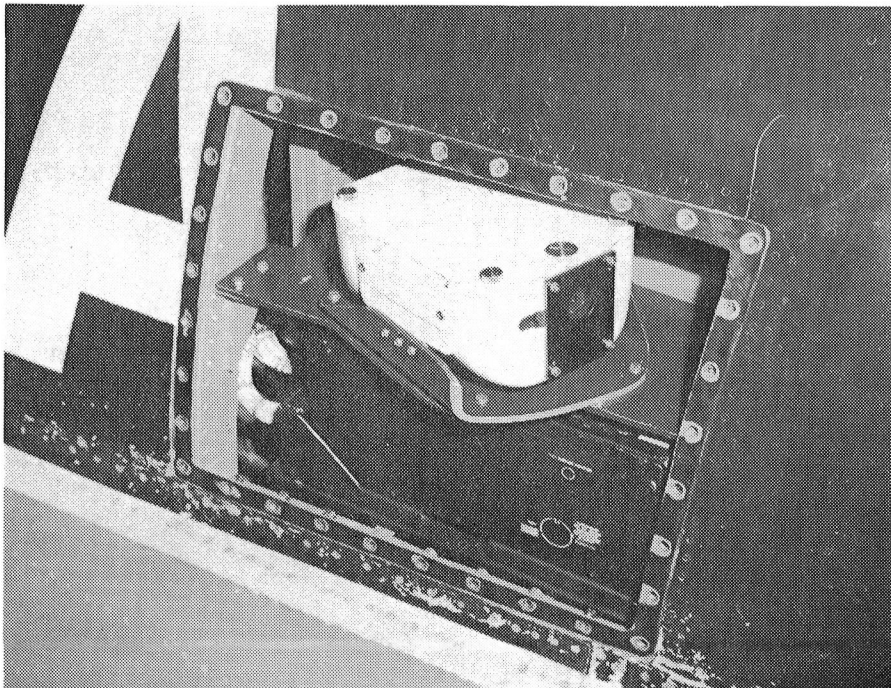
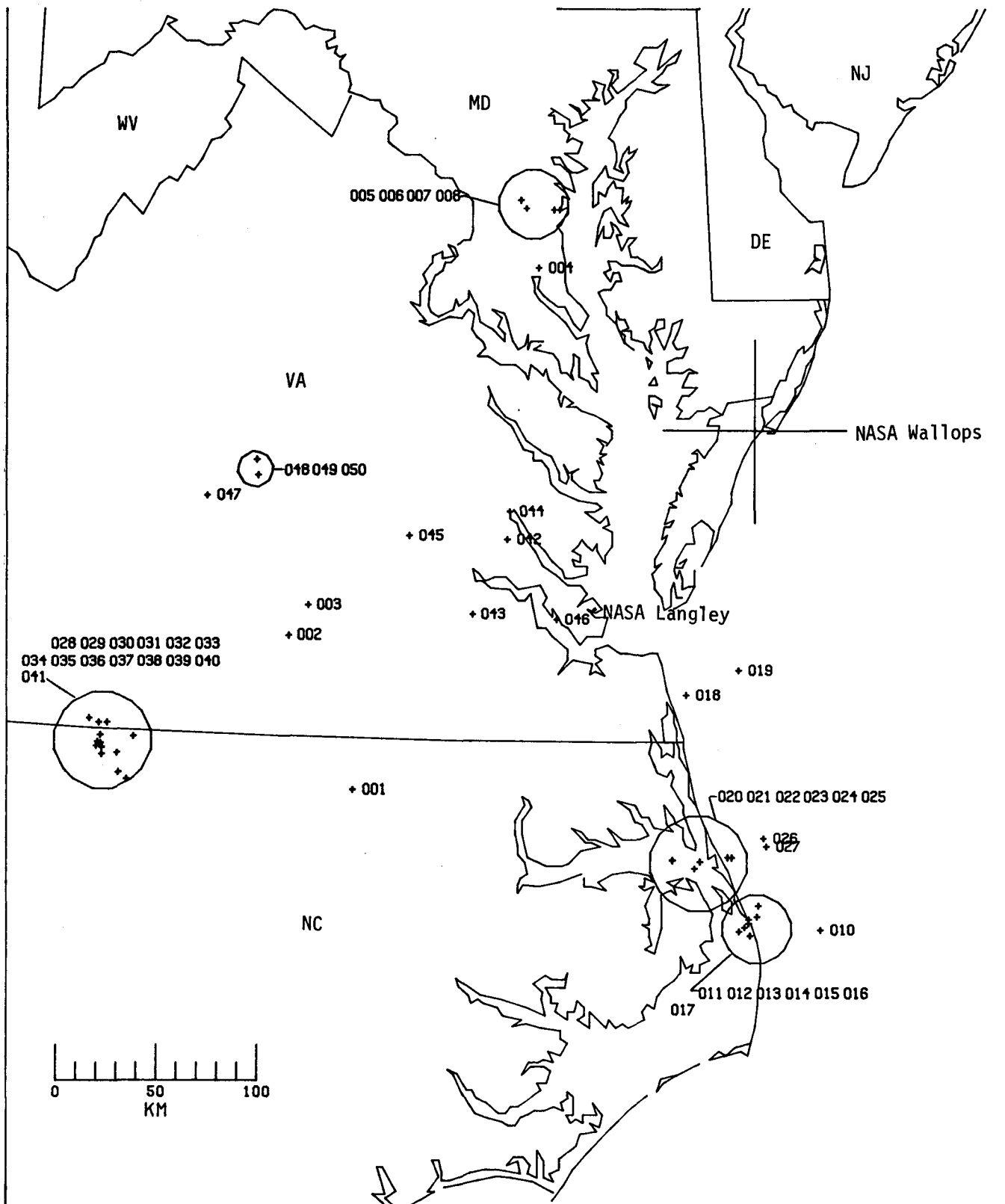
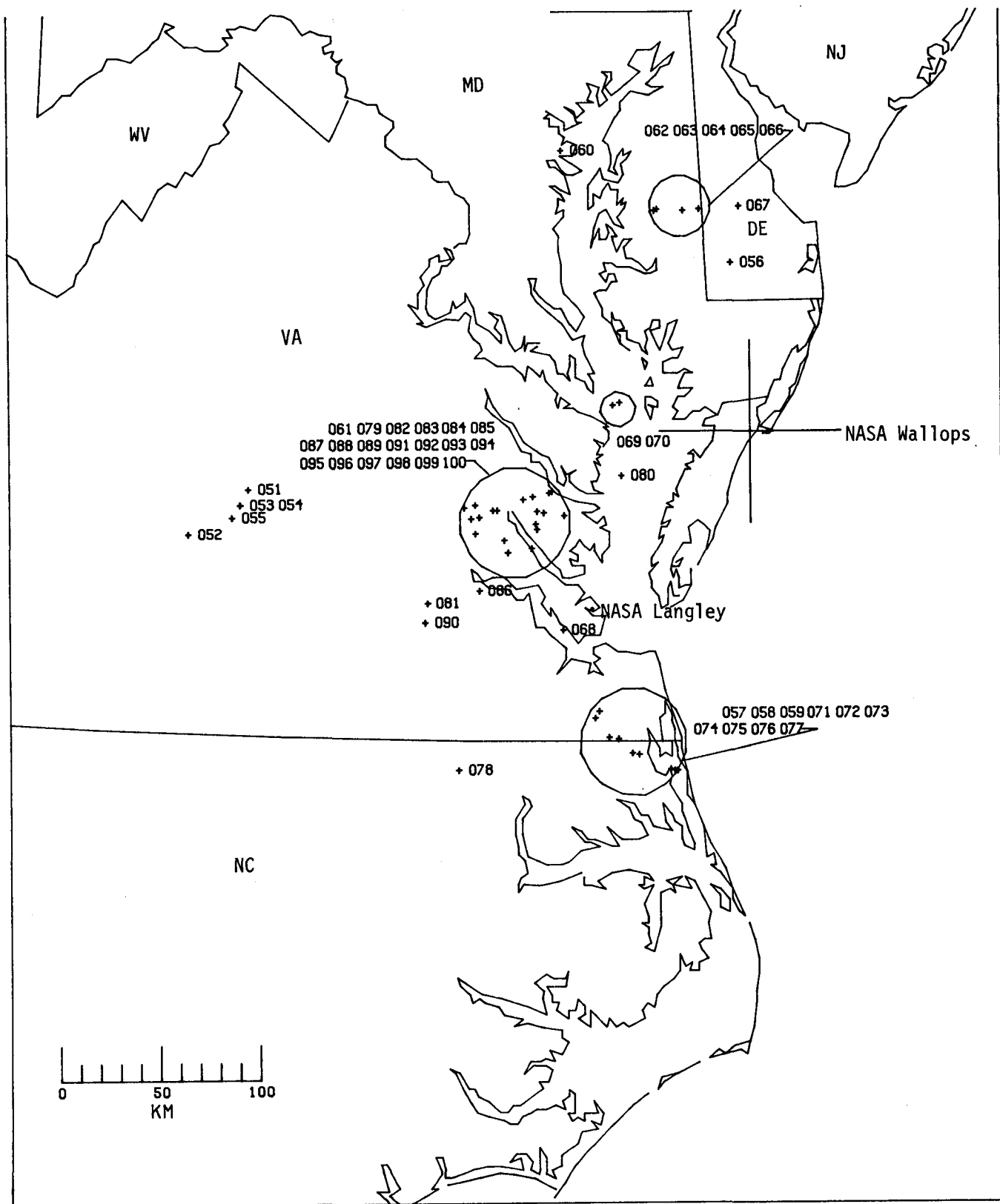


Figure 8. - Aft camera without shroud.



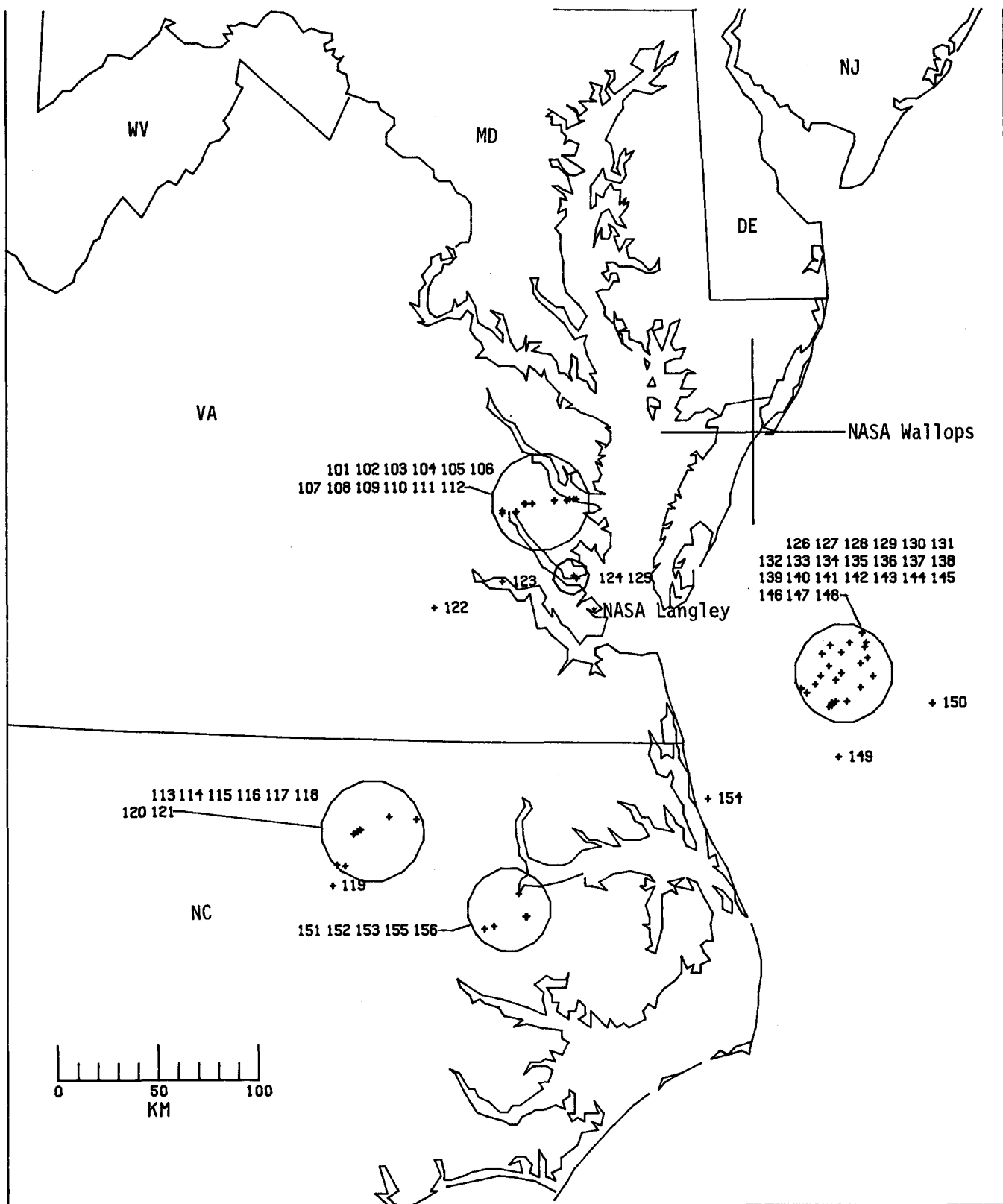
(a) Strikes 1-50.

Figure 9.- Geographical location of the F-106B research airplane at the time of each lightning event in 1982.



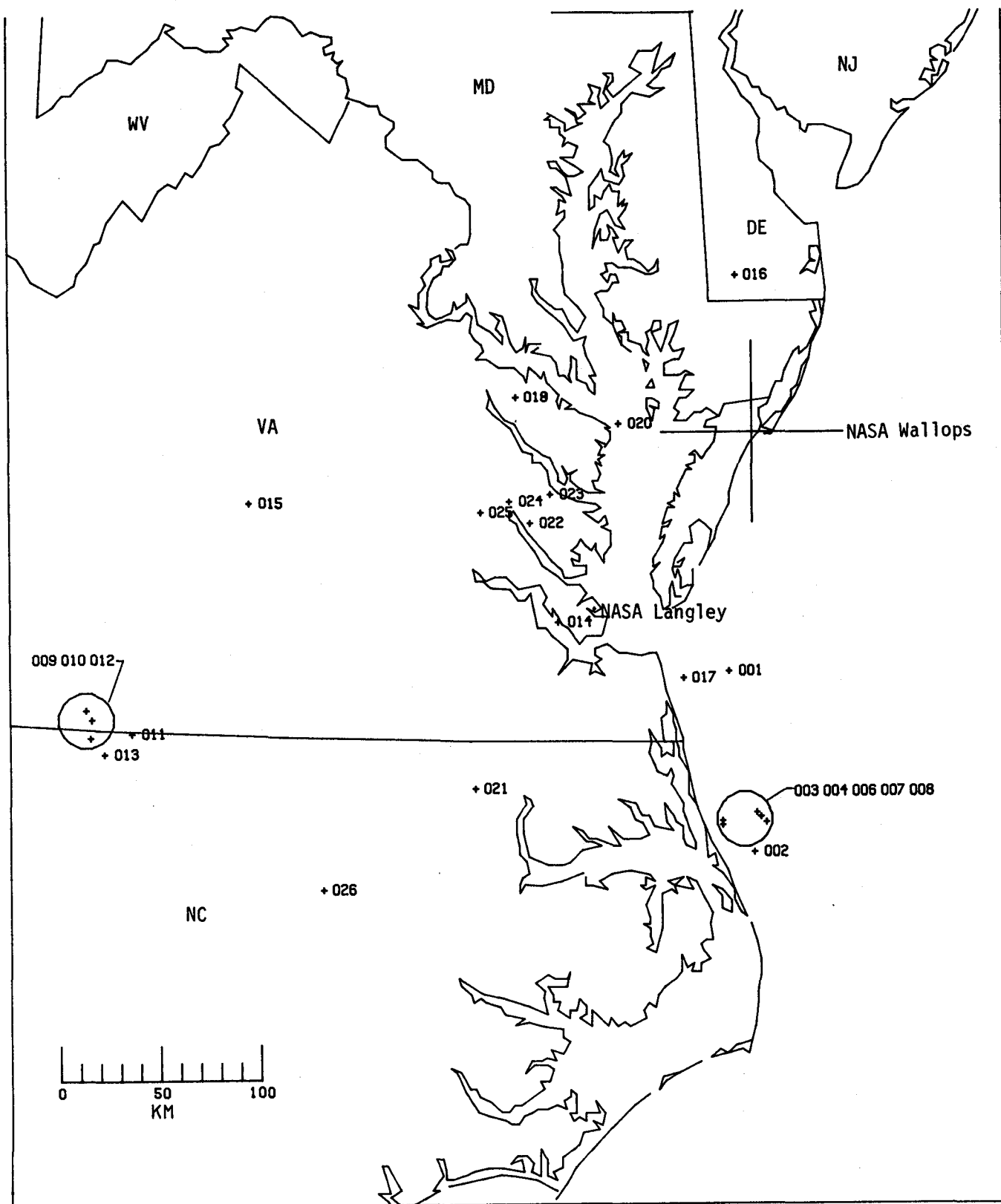
(b) Strikes 51-100.

Figure 9.- Continued.



(c) Strikes 101-156.

Figure 9.- Continued.



(d) Nearby flashes.

Figure 9.- Concluded.

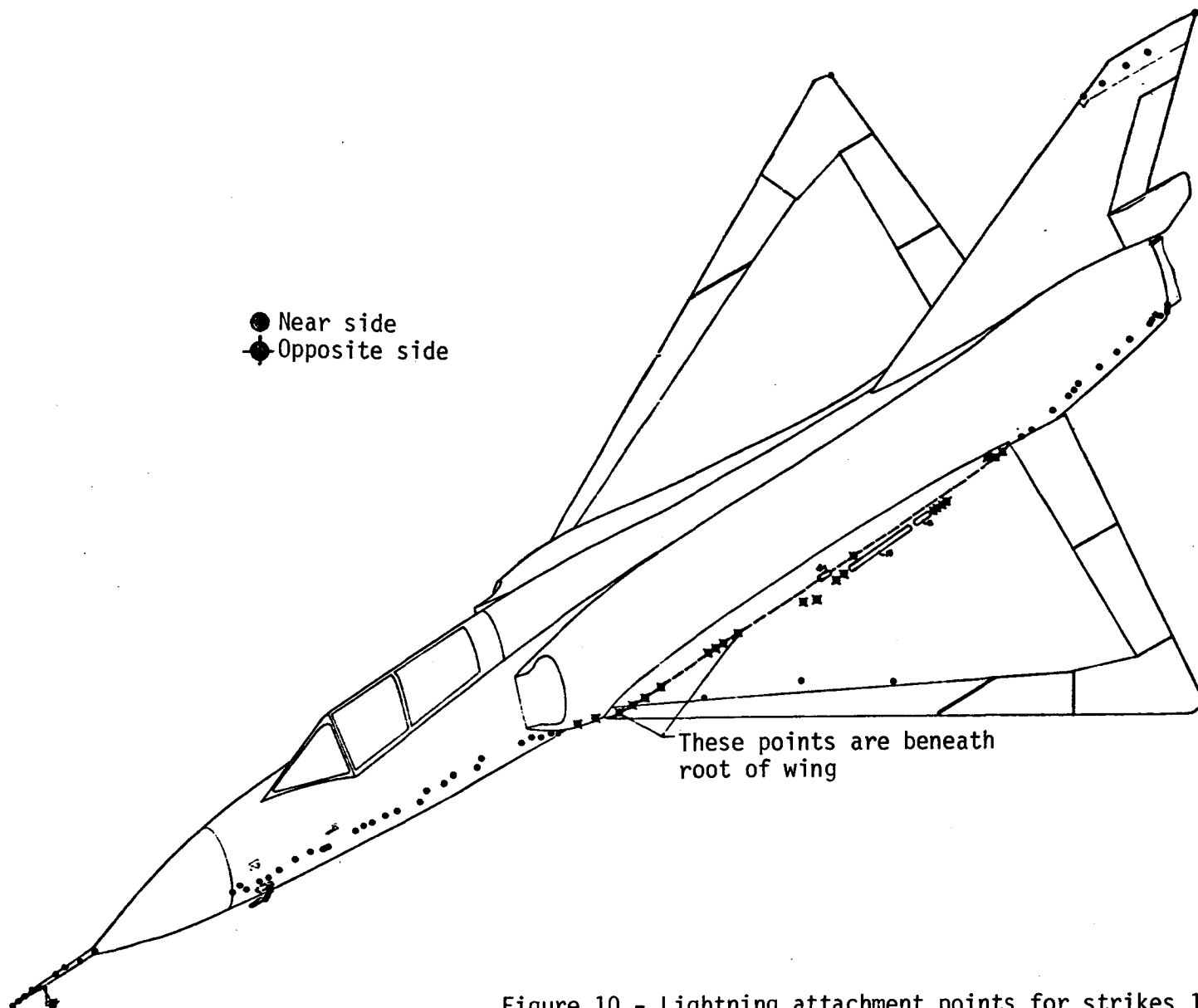


Figure 10.- Lightning attachment points for strikes 1-3, Flight 82-010.

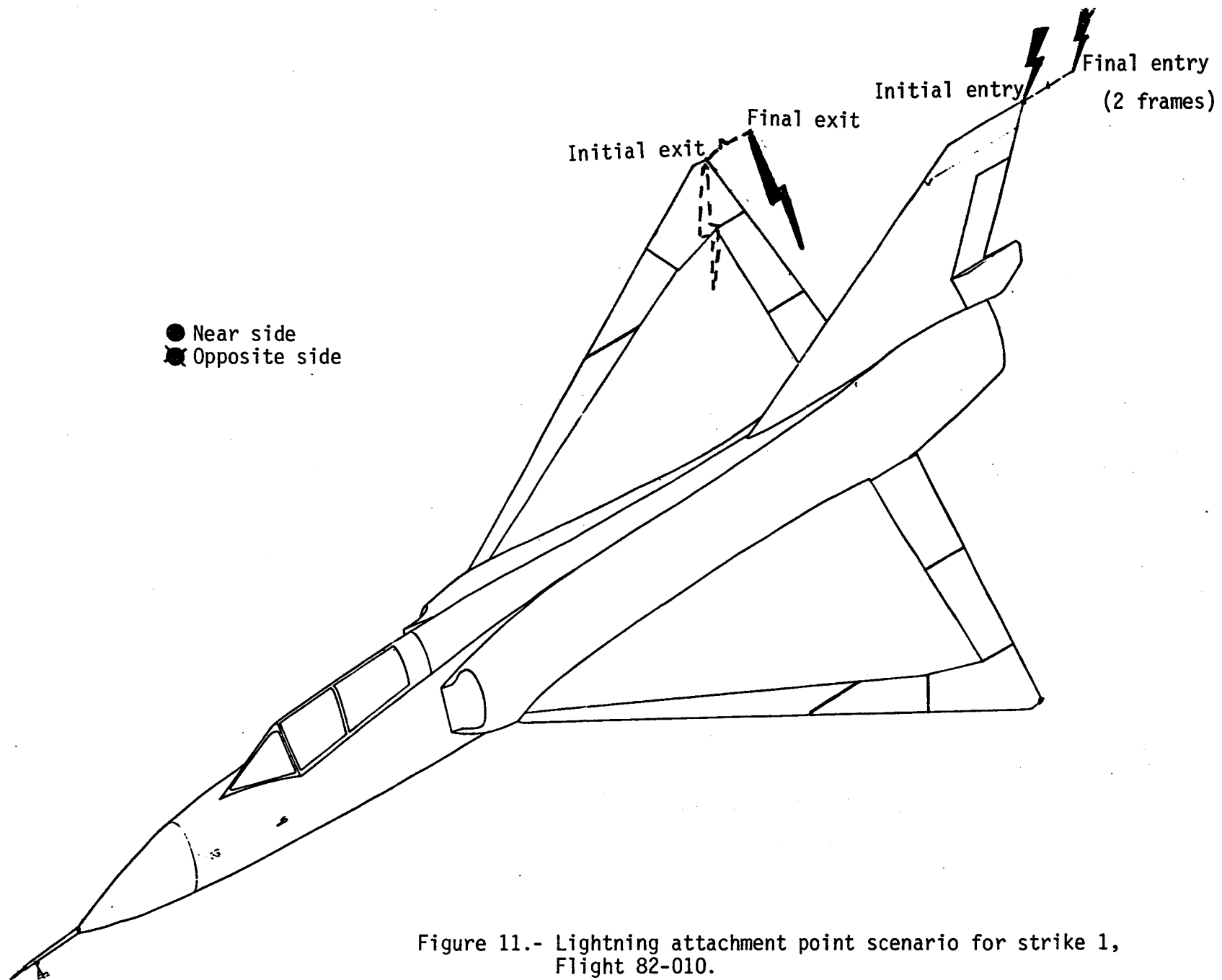


Figure 11.- Lightning attachment point scenario for strike 1, Flight 82-010.

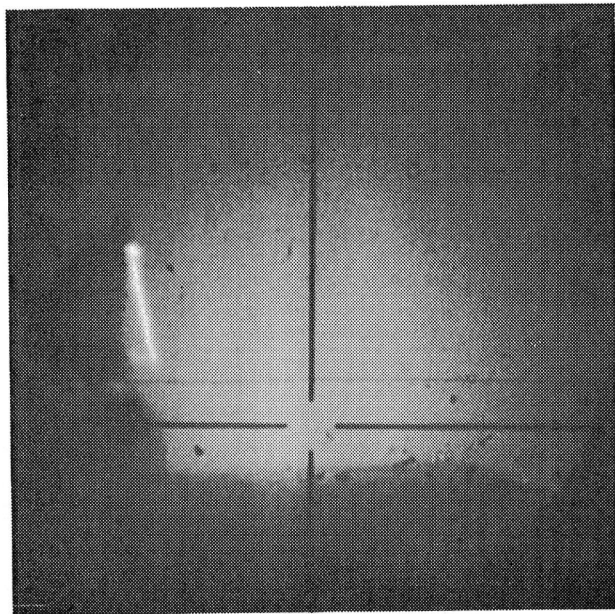


Figure 12. - Strike 1, Flight 82-010, aft camera.

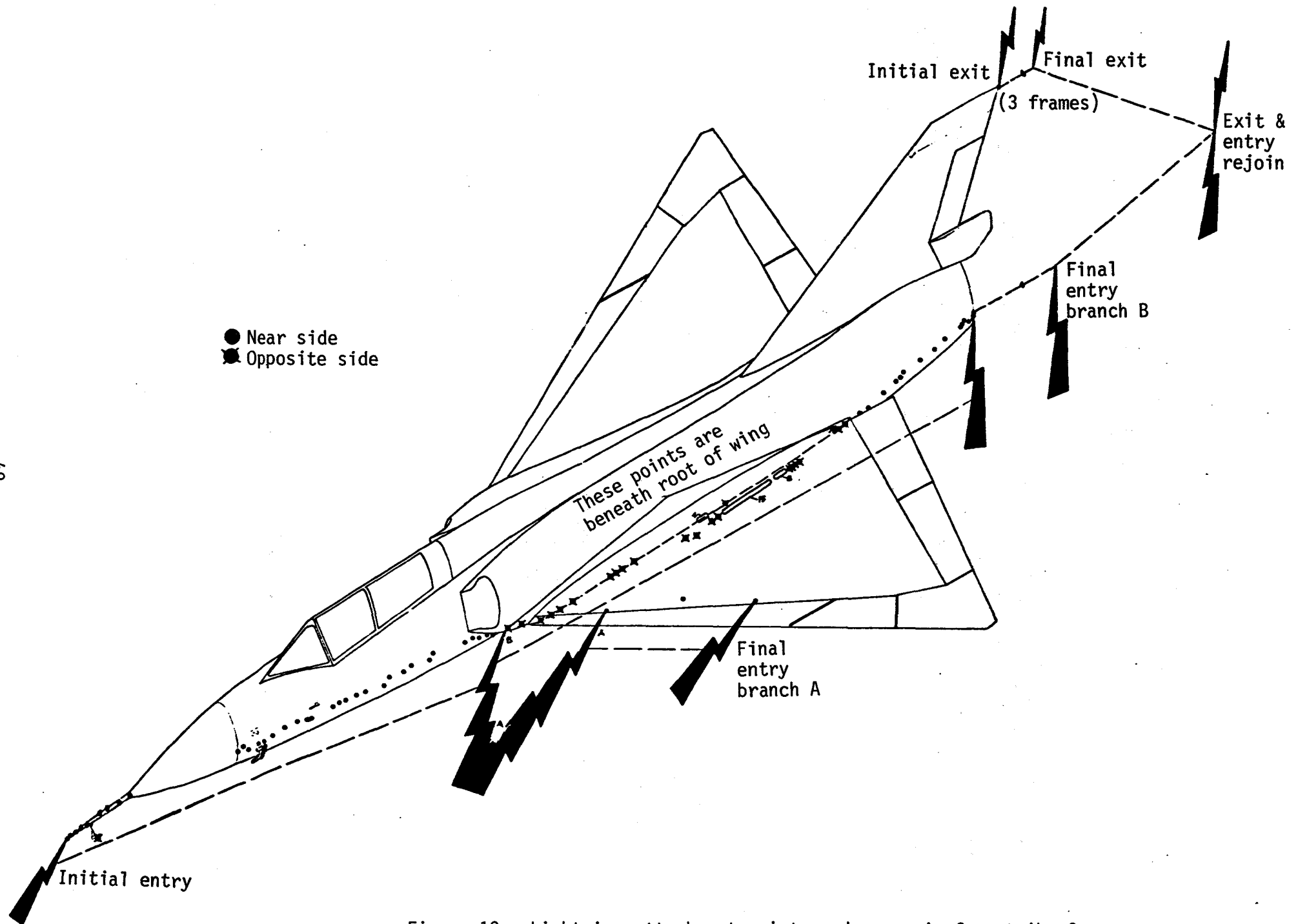


Figure 13.- Lightning attachment points and scenario for strike 2, Flight 82-010.

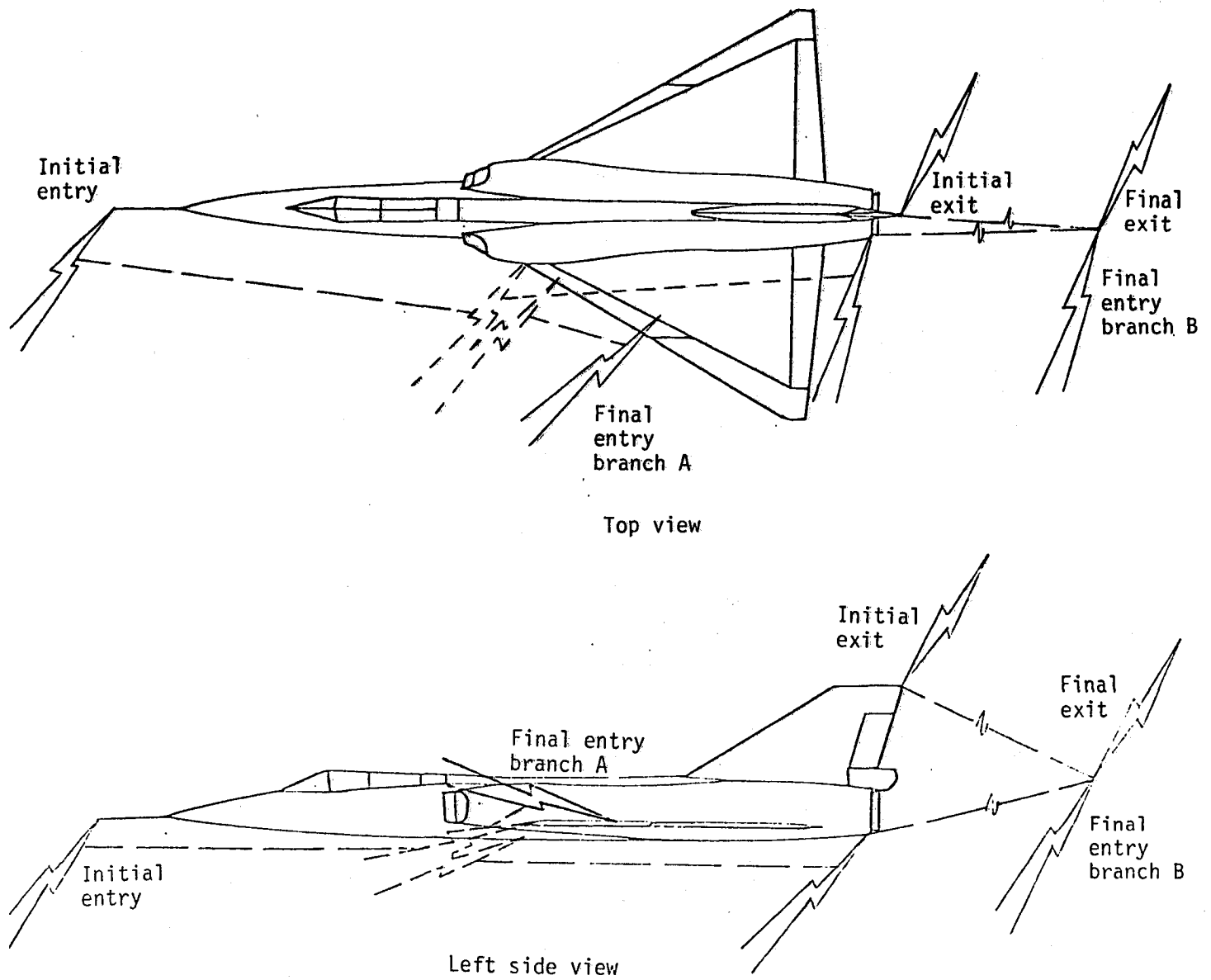


Figure 14.- Lightning attachment point scenario for strike 2, Flight 82-010.

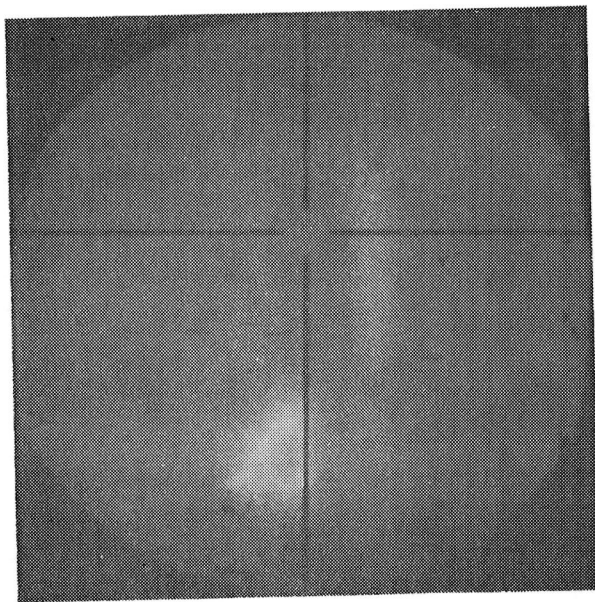
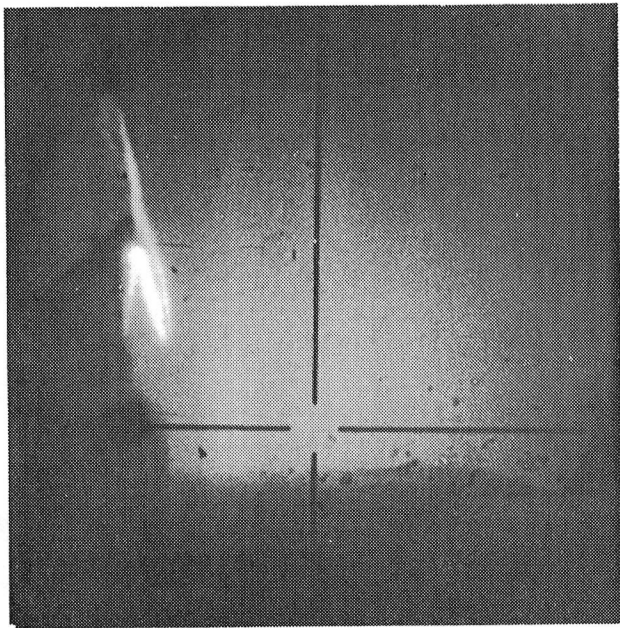
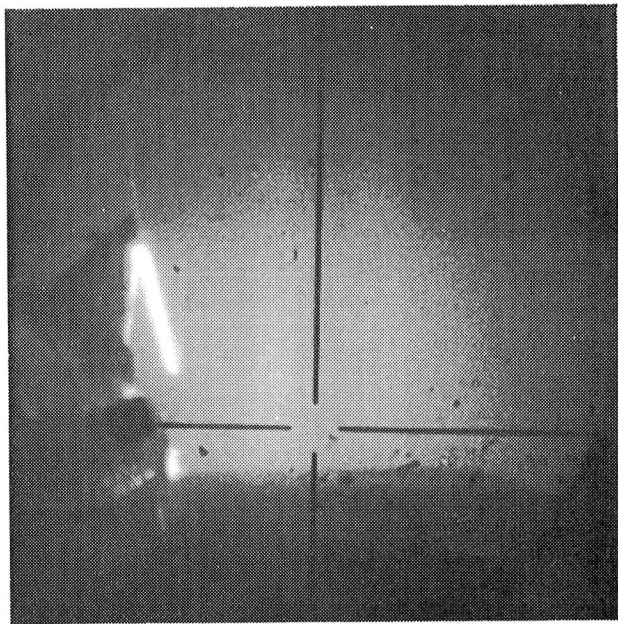


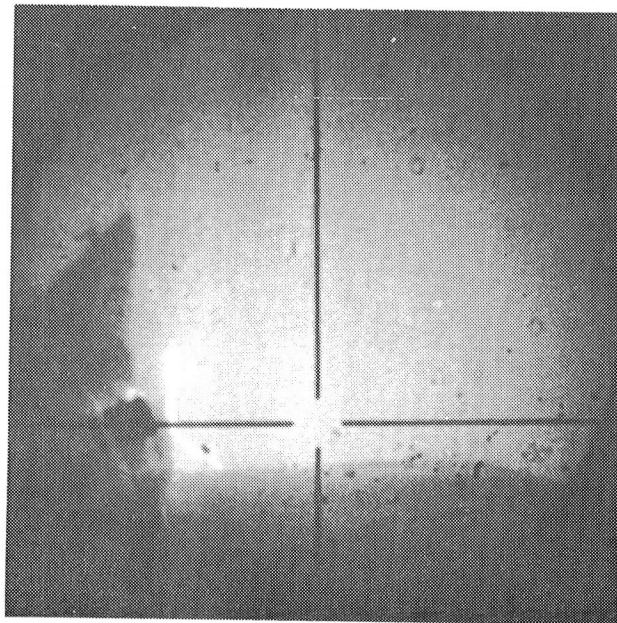
Figure 15. - Strike 2, Flight 82-010, forward camera.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 16. - Strike 2, Flight 82-010, aft camera.

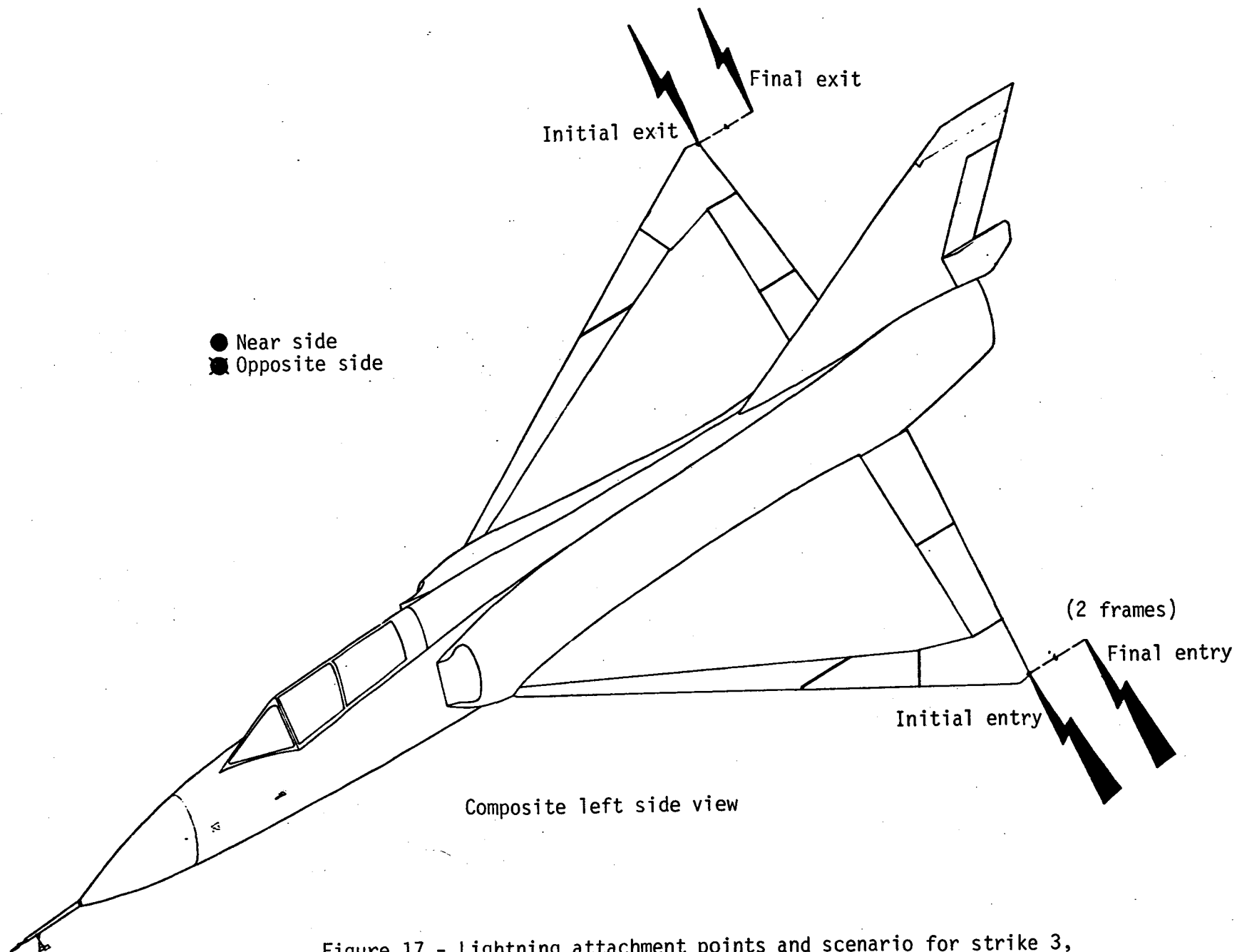


Figure 17.- Lightning attachment points and scenario for strike 3, Flight 82-010.

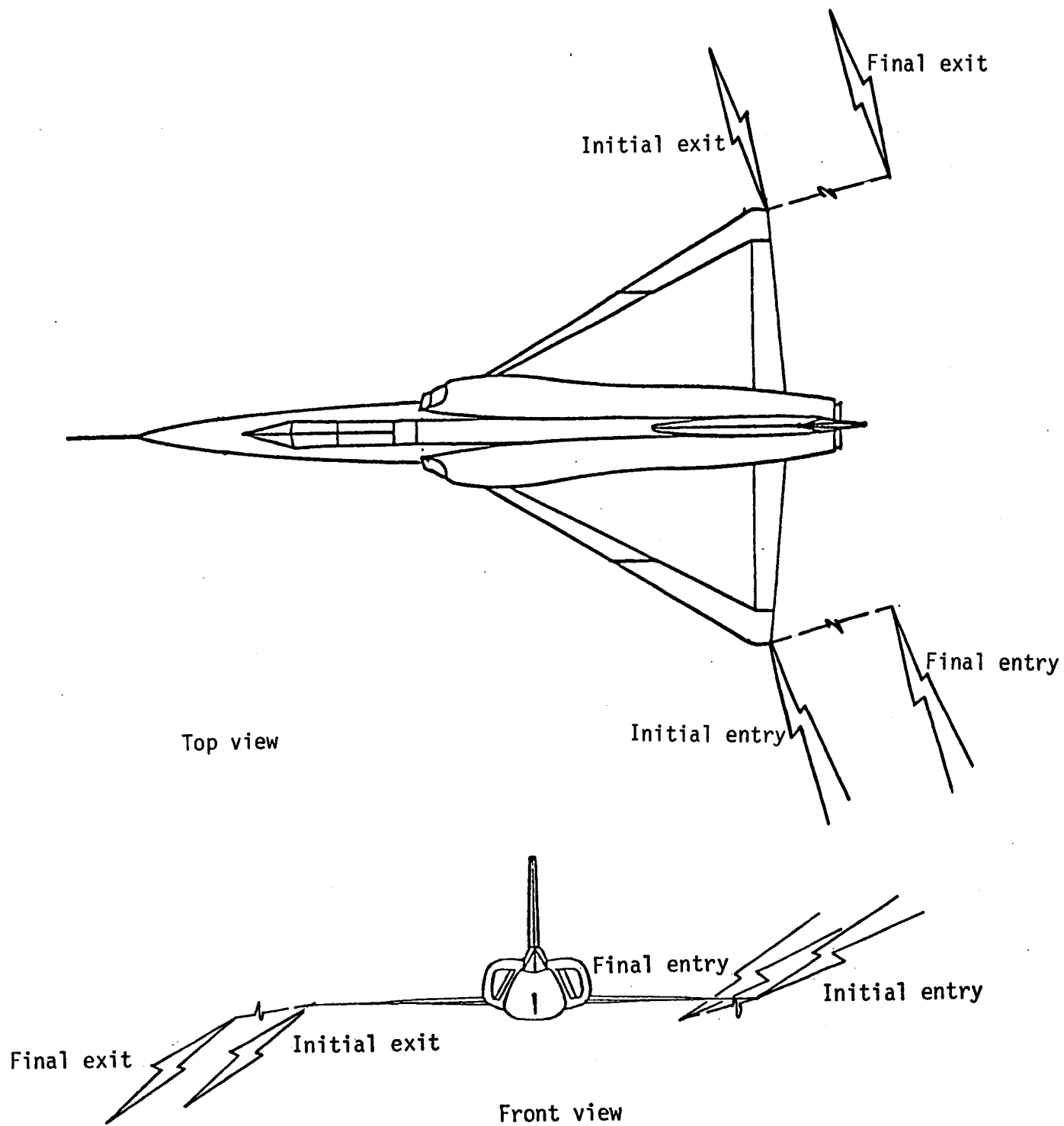
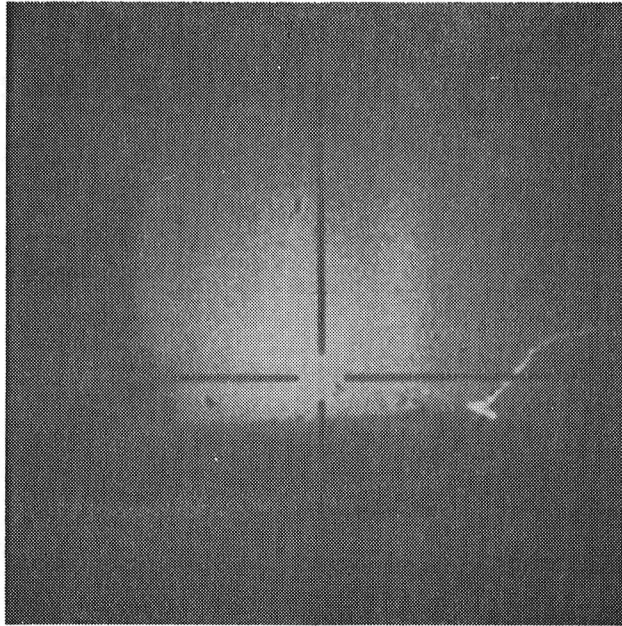
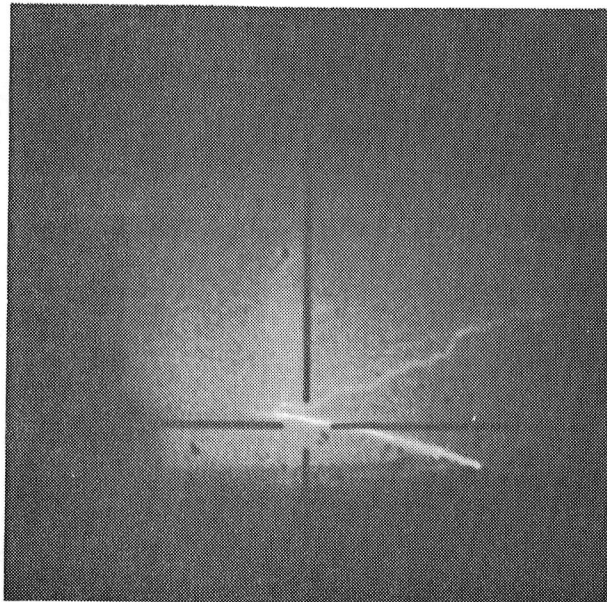


Figure 18.- Lightning attachment point scenario for strike 3, Flight 82-010.

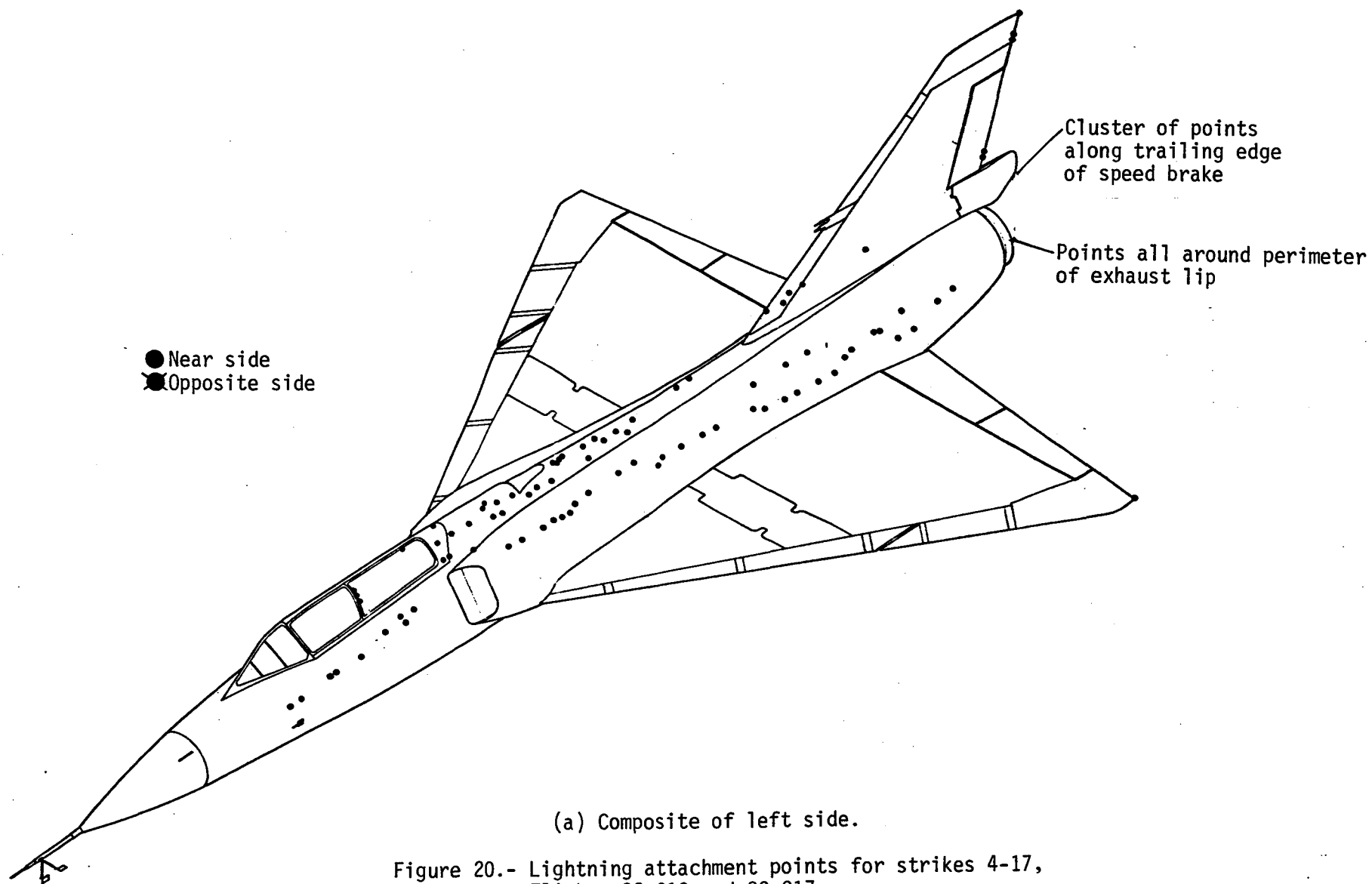


(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 19. - Strike 3, Flight 82-010, aft camera.



Cluster of points along
trailing edge of speed brake

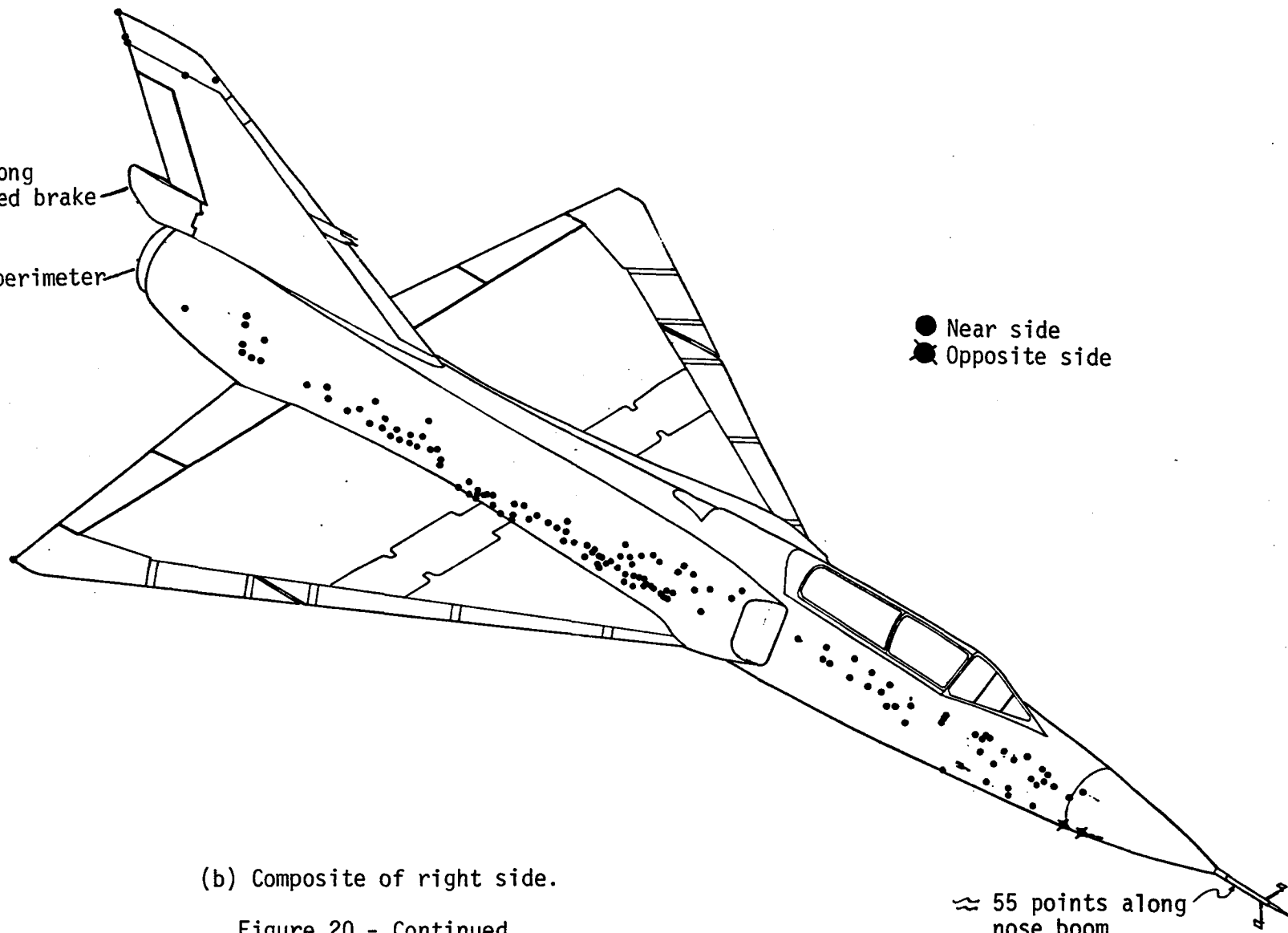
Points all around perimeter
of exhaust lip

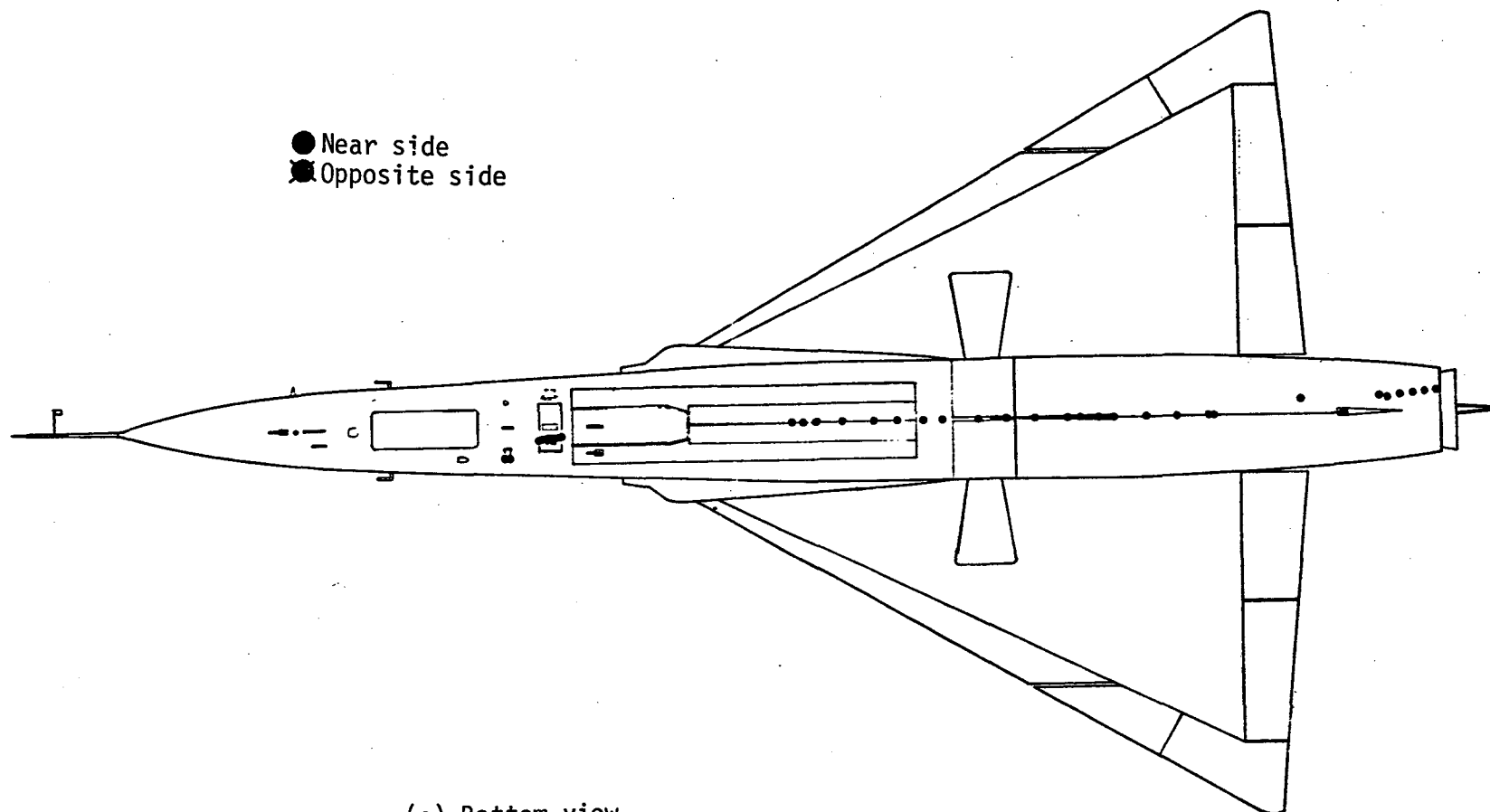
● Near side
⊗ Opposite side

≈ 55 points along
nose boom

(b) Composite of right side.

Figure 20.- Continued.





(c) Bottom view.

Figure 20.- Concluded.

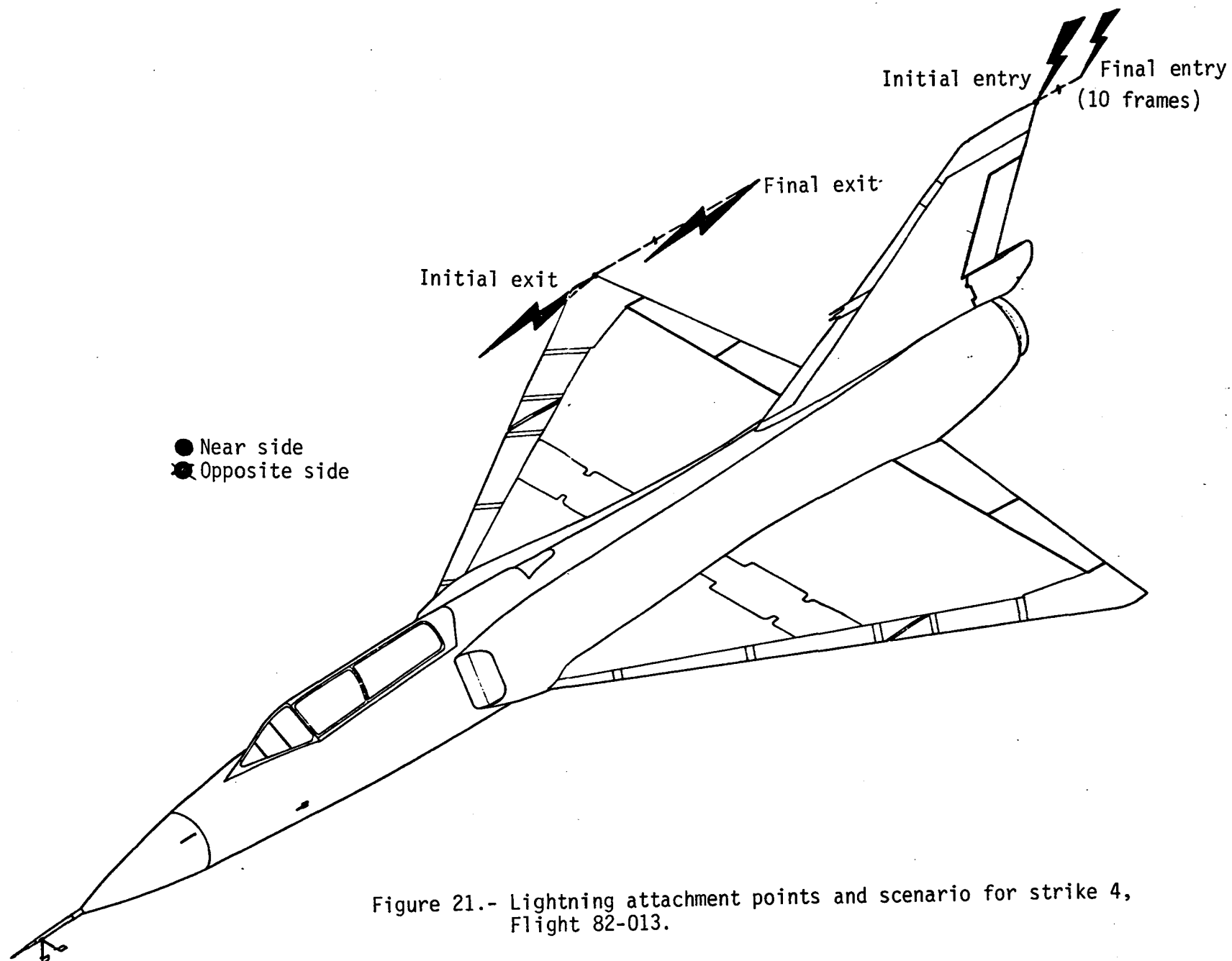
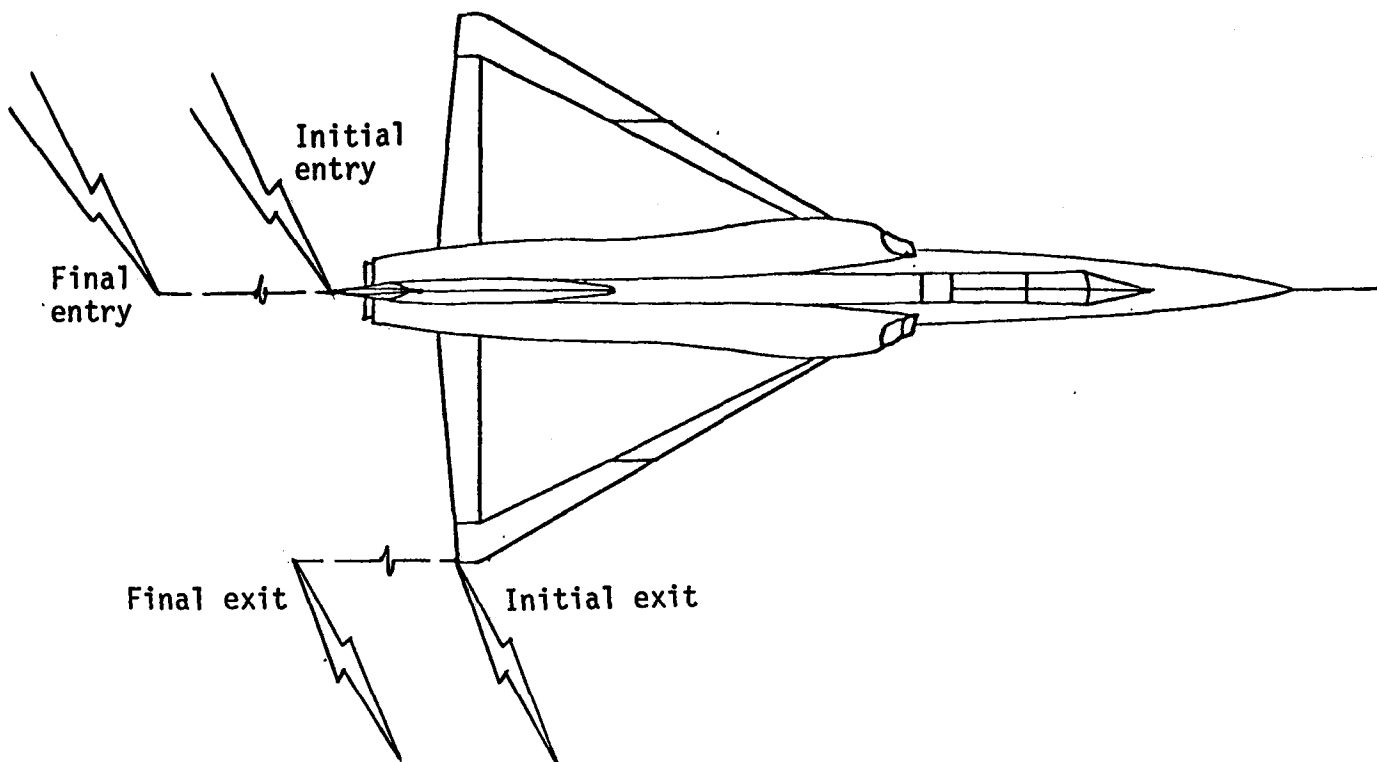
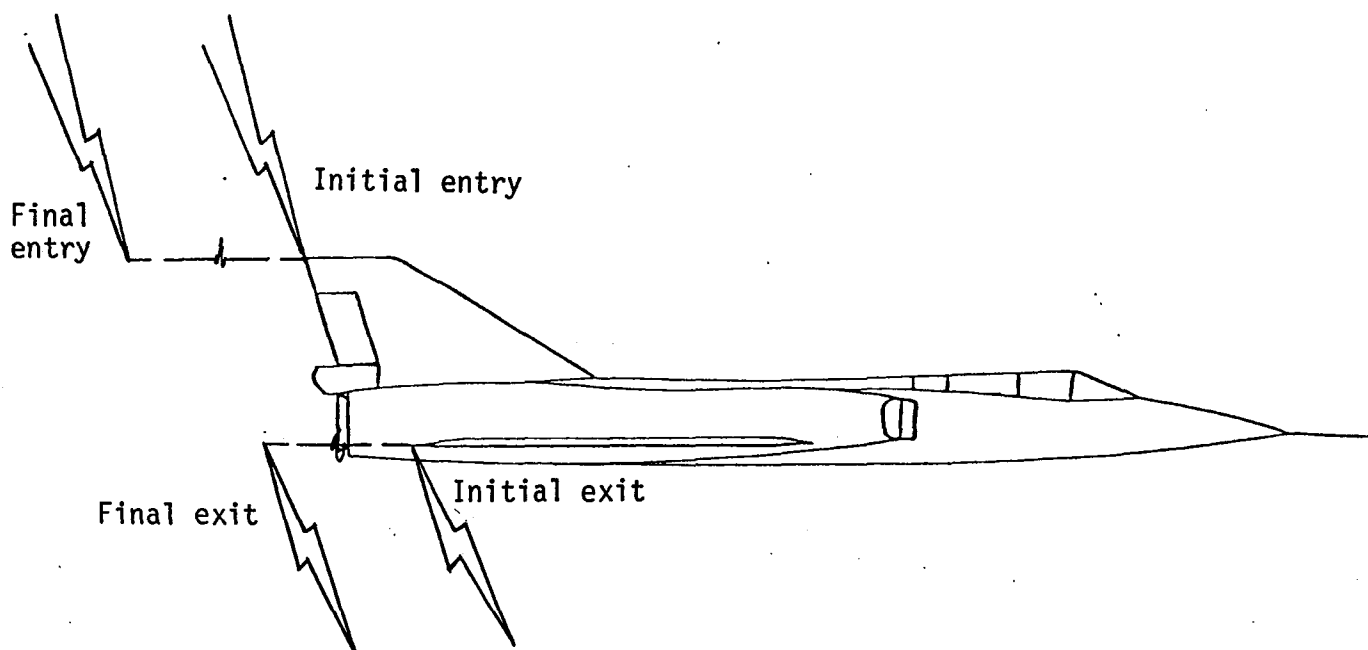


Figure 21.- Lightning attachment points and scenario for strike 4, Flight 82-013.

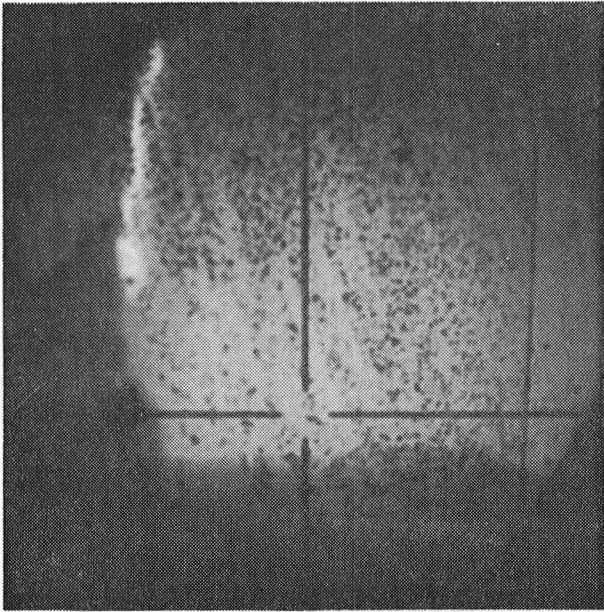


Top view

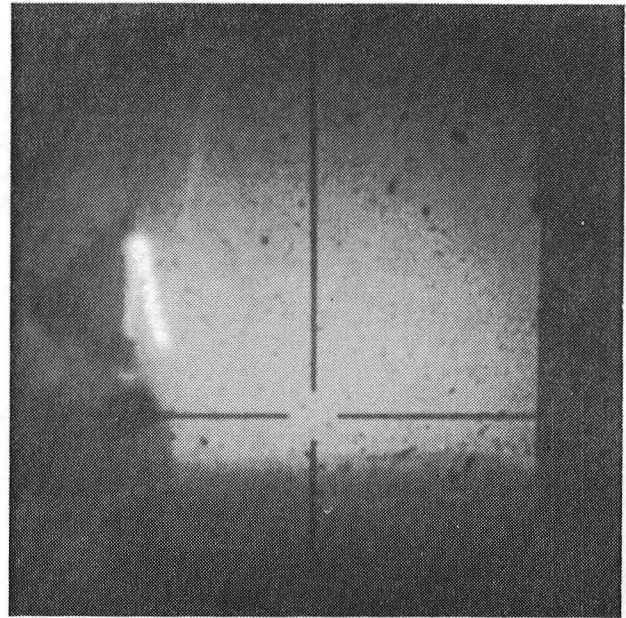


Right side view

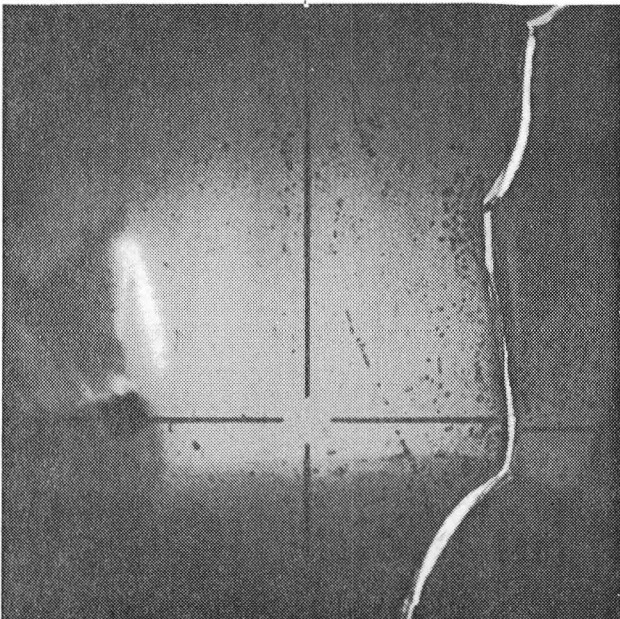
Figure 22.- Lightning attachment point scenario for strike 4, Flight 82-013.



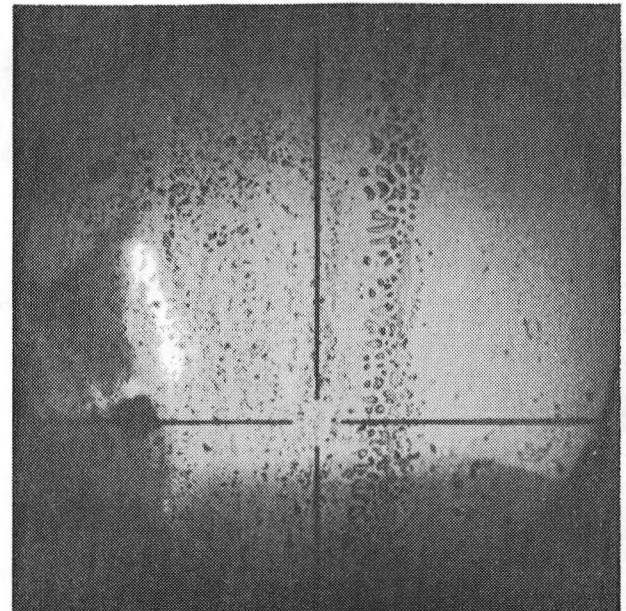
(a) Frame 1 of 9.



(b) Frame 2 of 9.

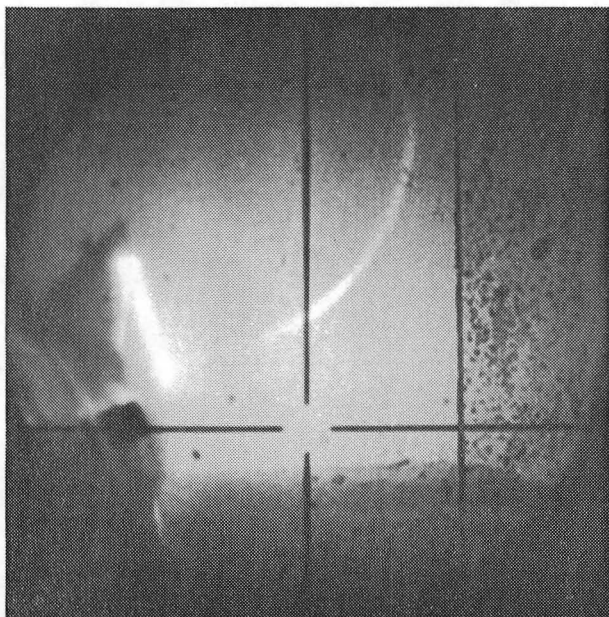


(c) Frame 3 of 9.



(d) Frame 4 of 9.

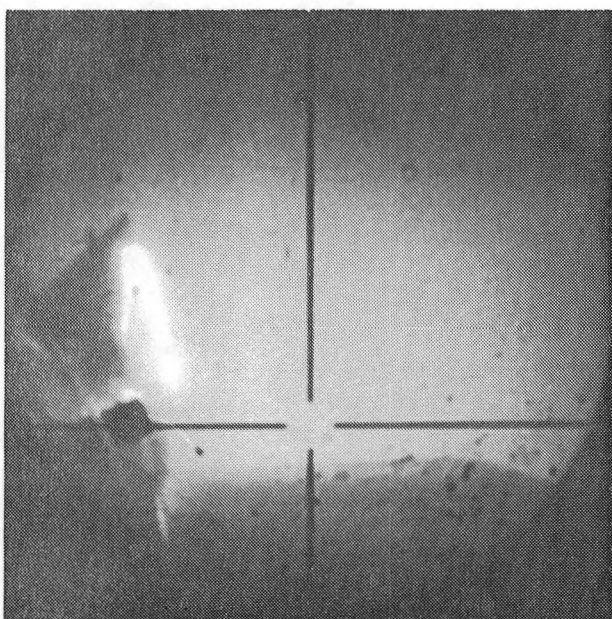
Figure 23. - Strike 4, Flight 82-013, aft camera. Original film damaged by tear and tape.



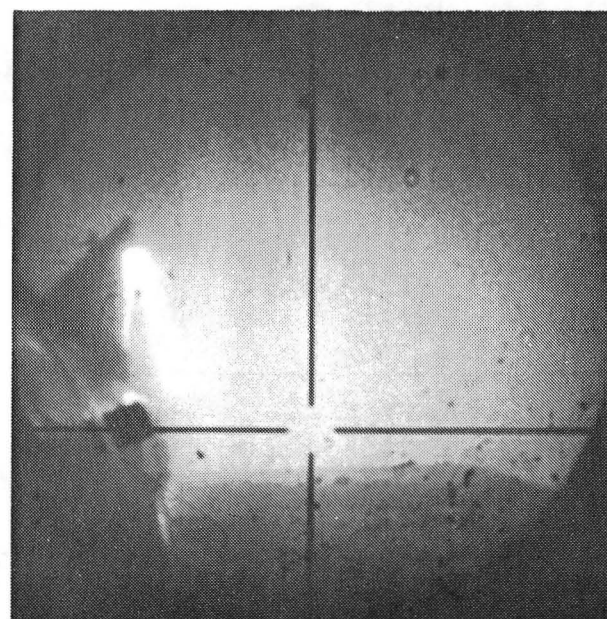
(e) Frame 5 of 9.



(f) Frame 6 of 9.

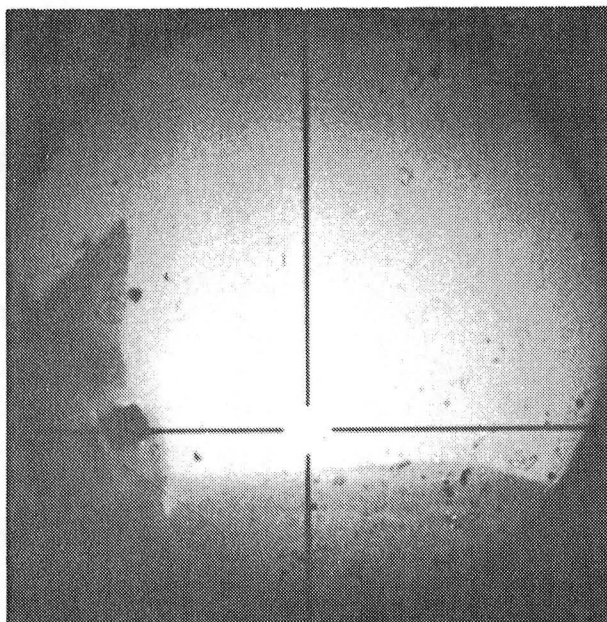


(g) Frame 7 of 9.



(h) Frame 8 of 9.

Figure 23. - Continued.



(i) Frame 9 of 9.

Figure 23. - Concluded.

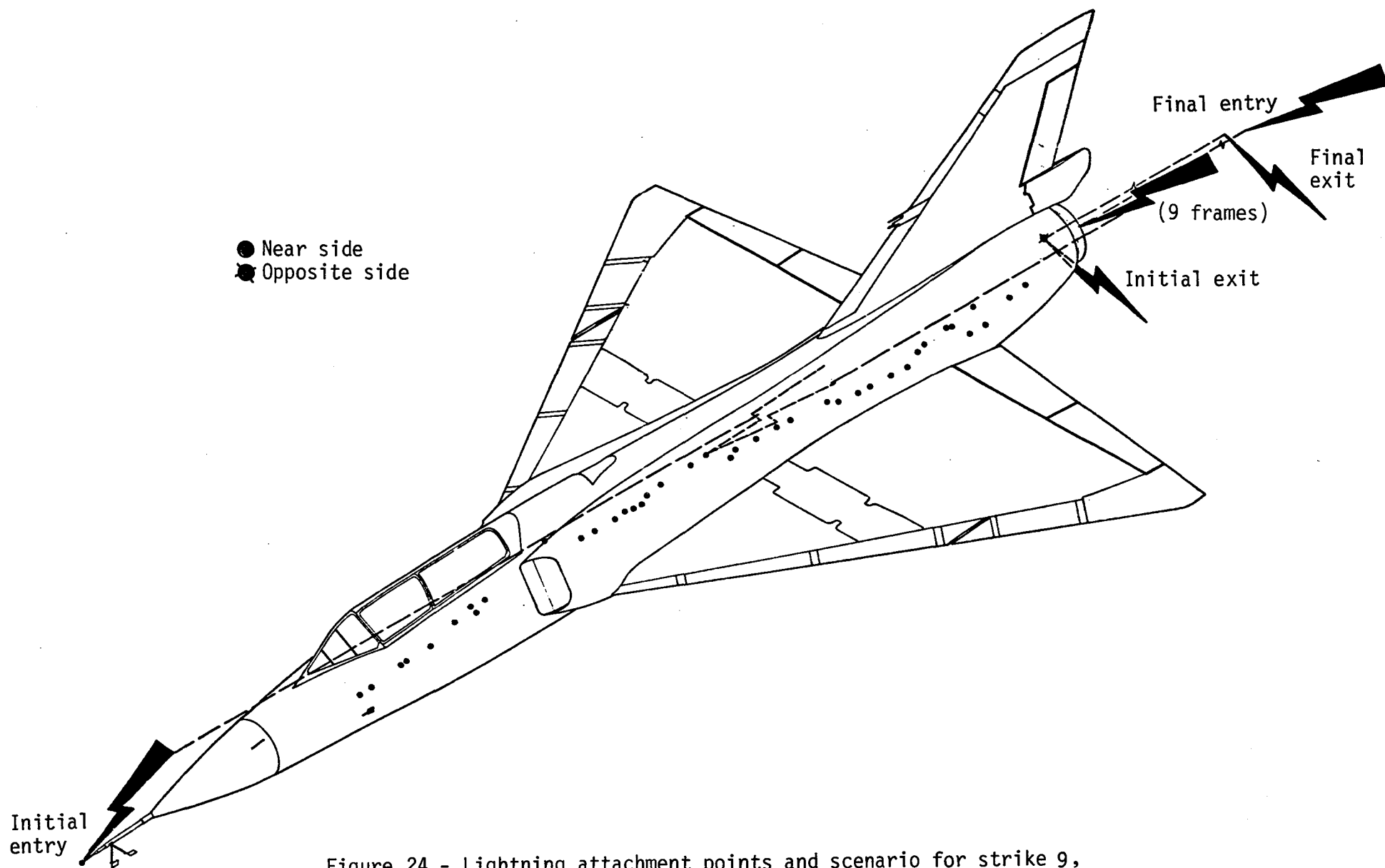


Figure 24.- Lightning attachment points and scenario for strike 9, Flight 82-017.

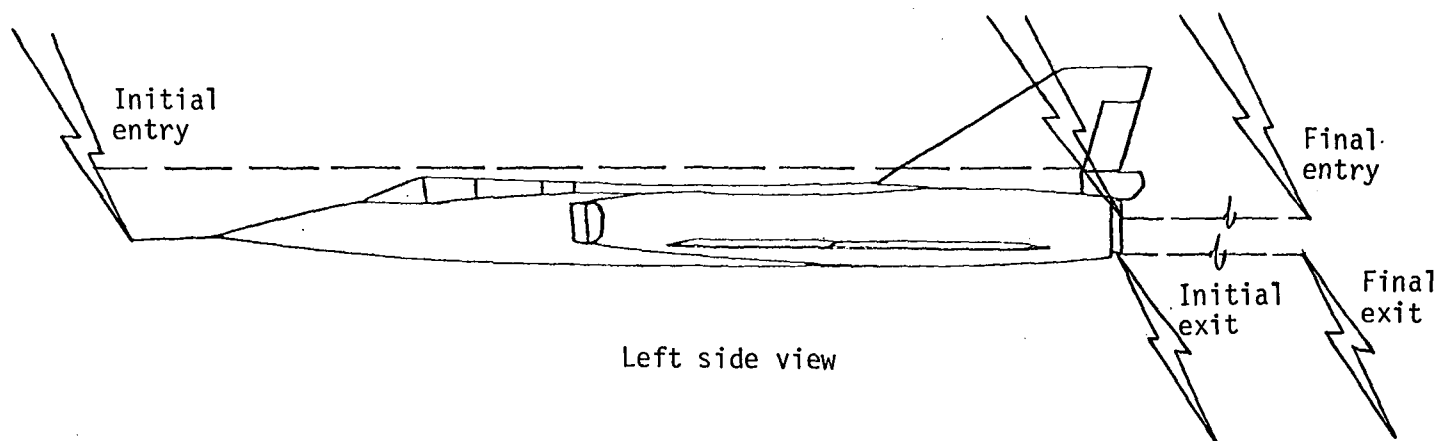
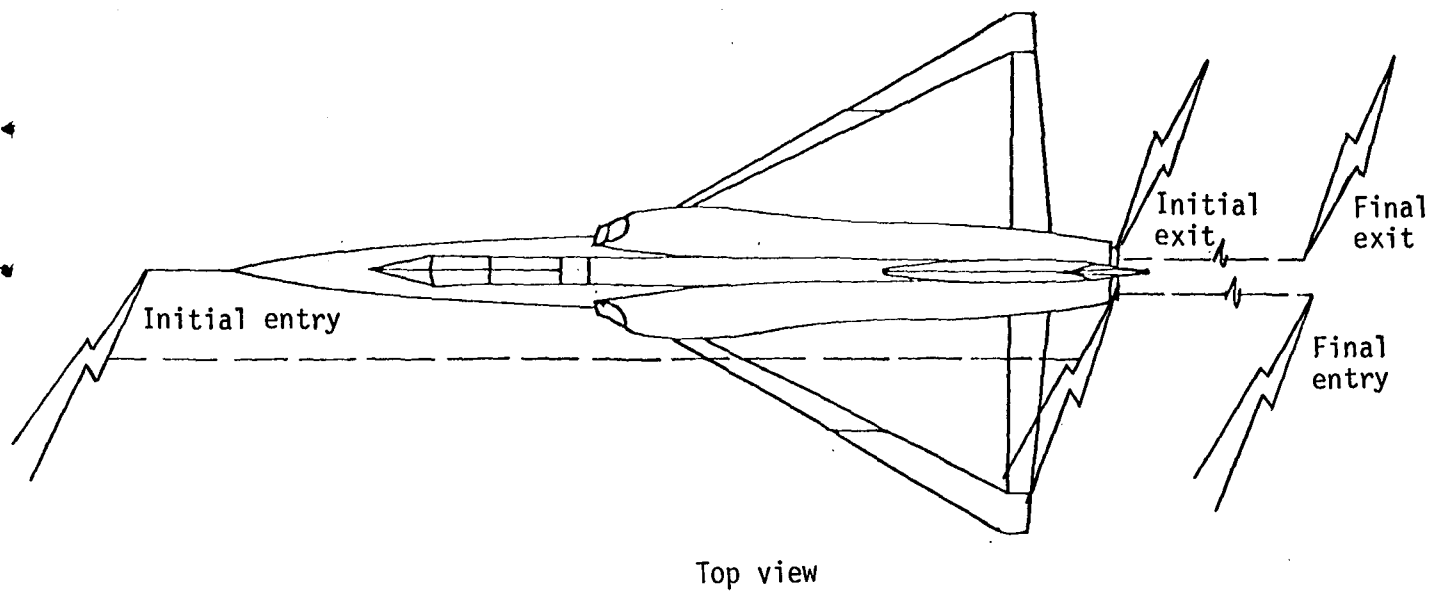
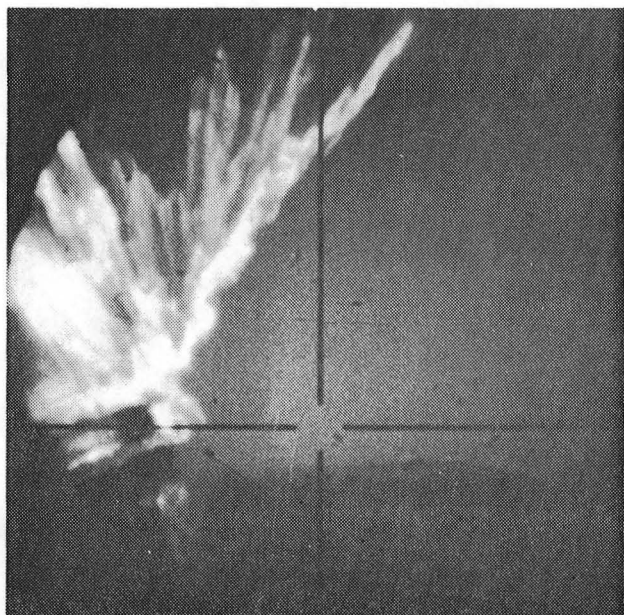
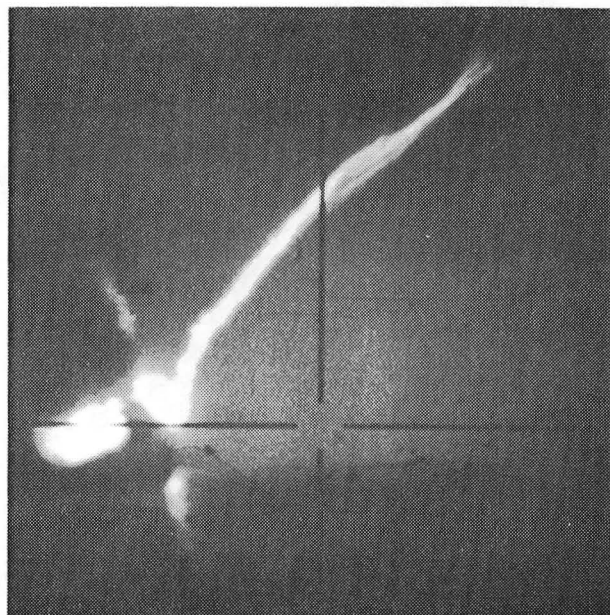


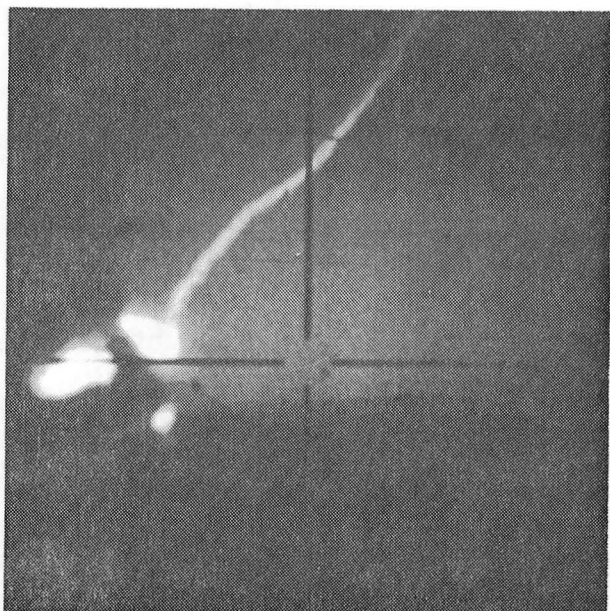
Figure 25.- Lightning attachment point scenario for strike 9, Flight 82-017.



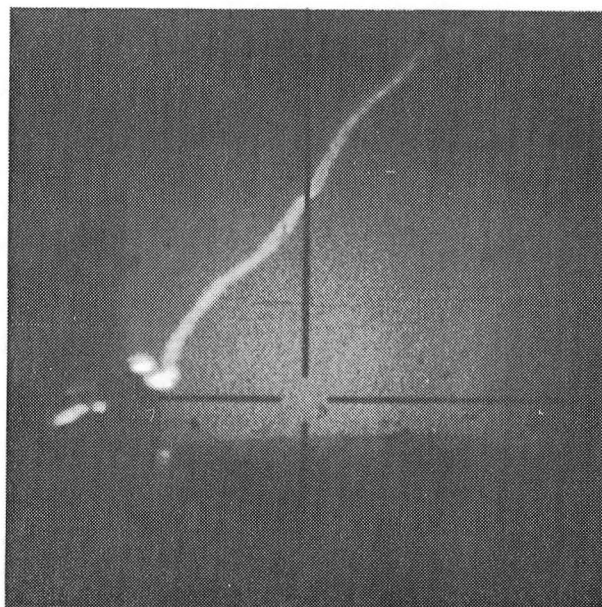
(a) Frame 1 of 9.



(b) Frame 2 of 9.

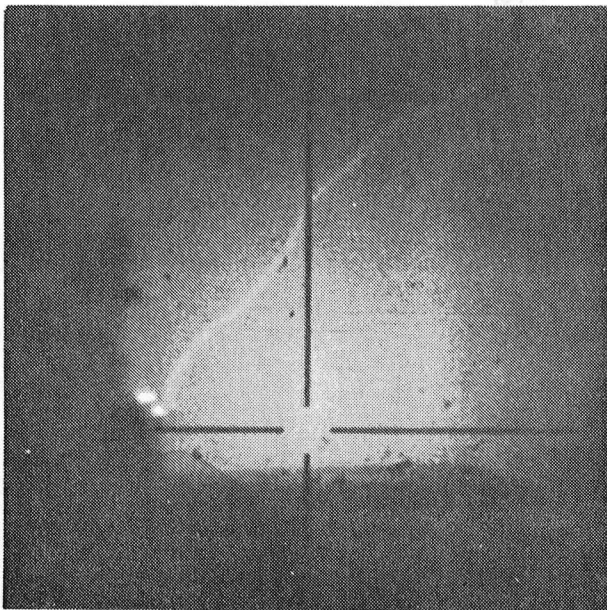


(c) Frame 3 of 9.

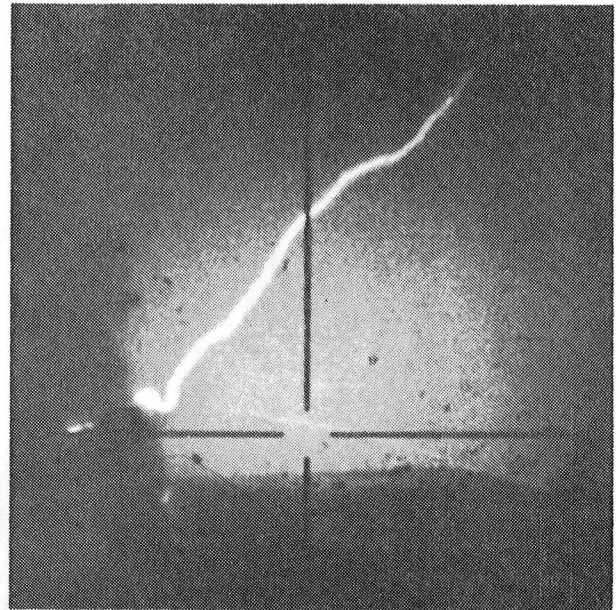


(d) Frame 4 of 9.

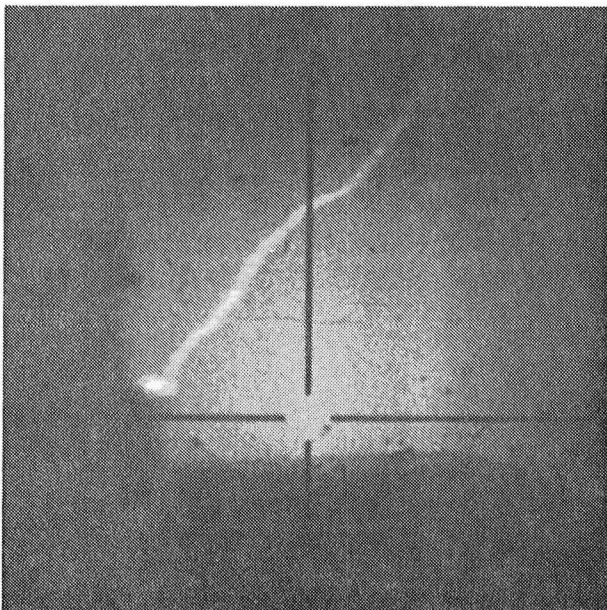
Figure 26. - Strike 9, Flight 82-017, aft camera.



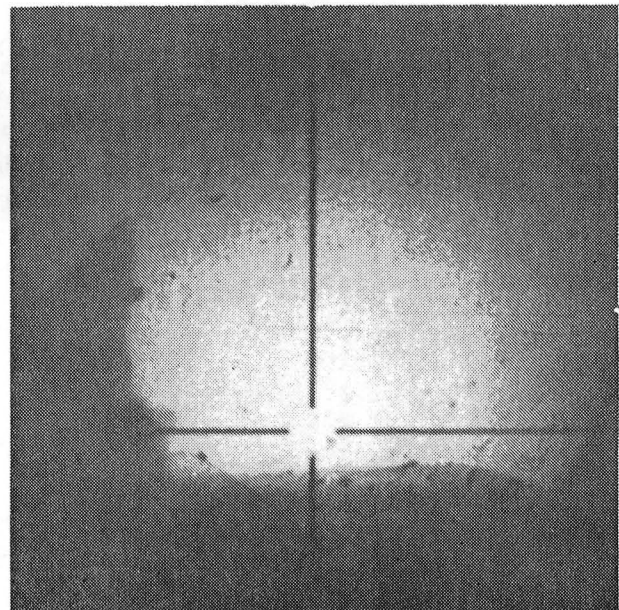
(e) Frame 5 of 9.



(f) Frame 6 of 9.

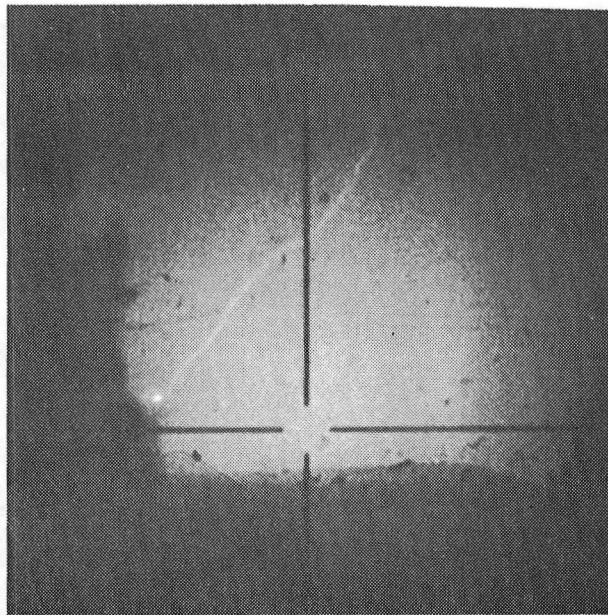


(g) Frame 7 of 9.



(h) Frame 8 of 9.

Figure 26. - Continued.



(i) Frame 9 of 9.

Figure 26. - Concluded.

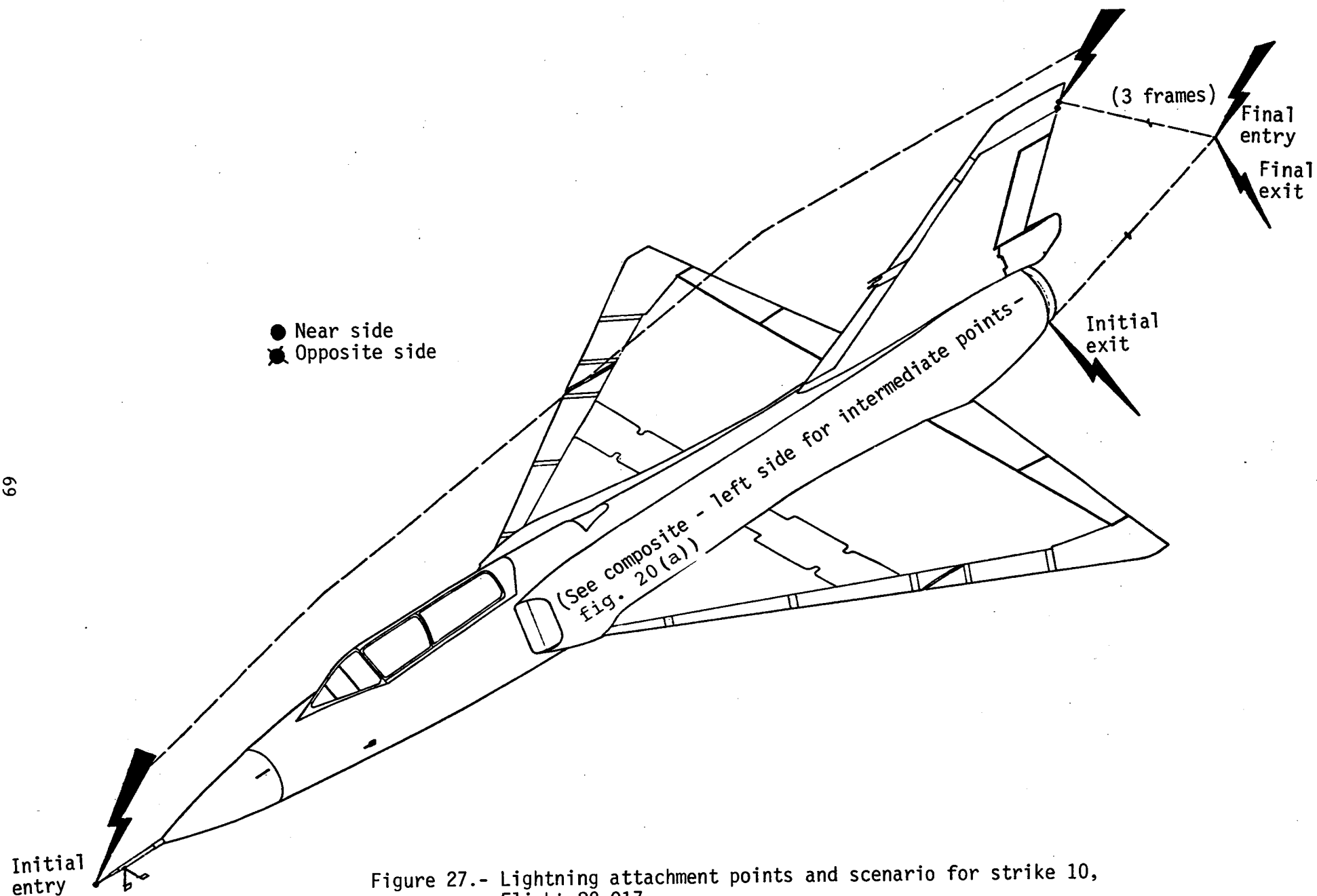
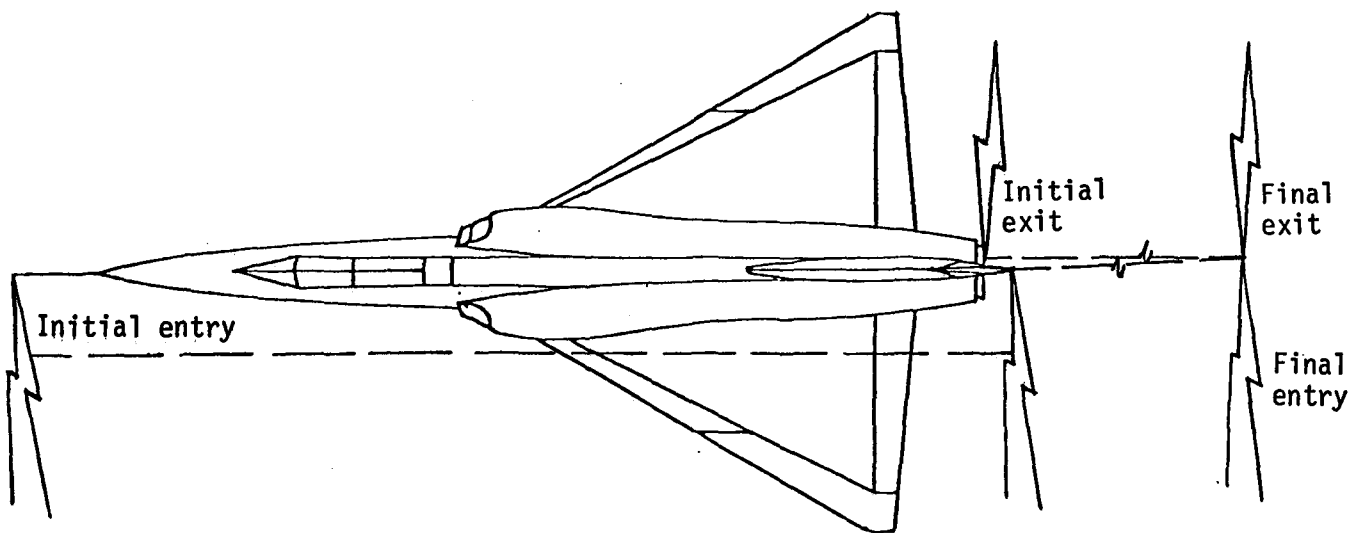
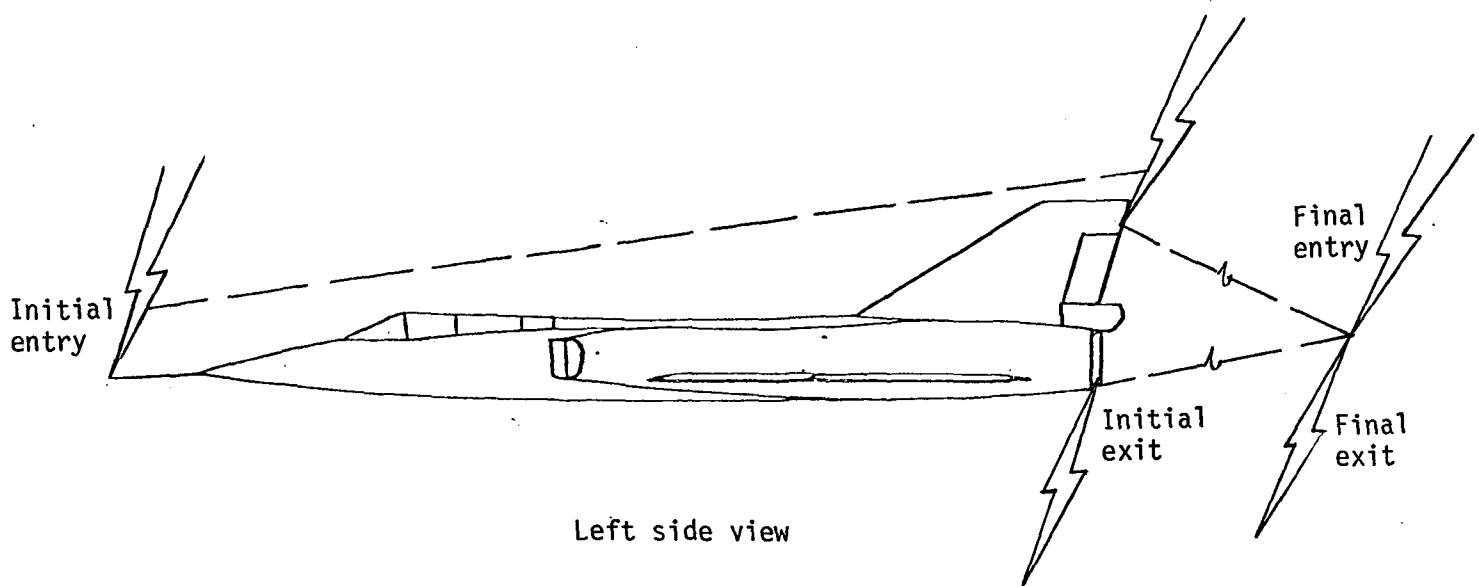


Figure 27.- Lightning attachment points and scenario for strike 10, Flight 82-017.



Top view



Left side view

Figure 28.- Lightning attachment point scenario for strike 10,
Flight 82-017.

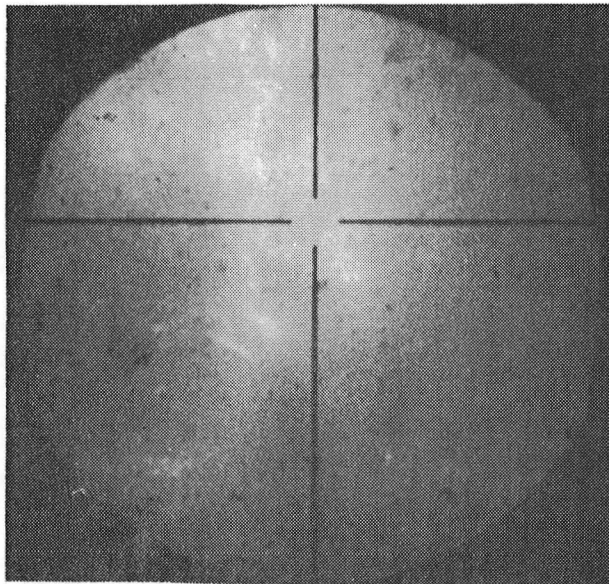
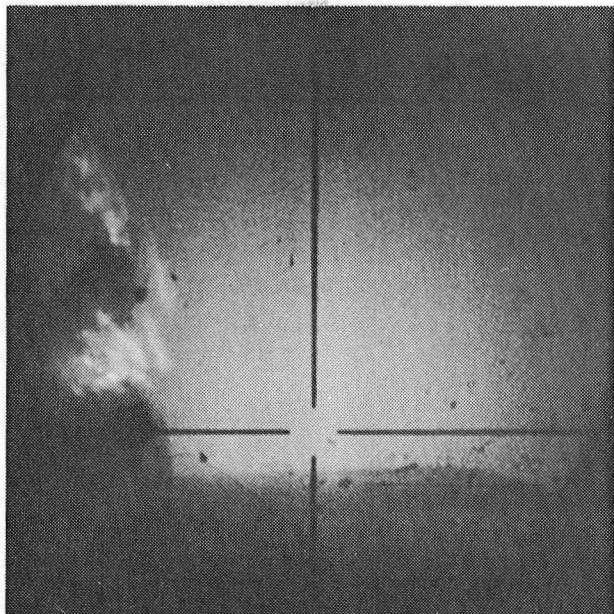
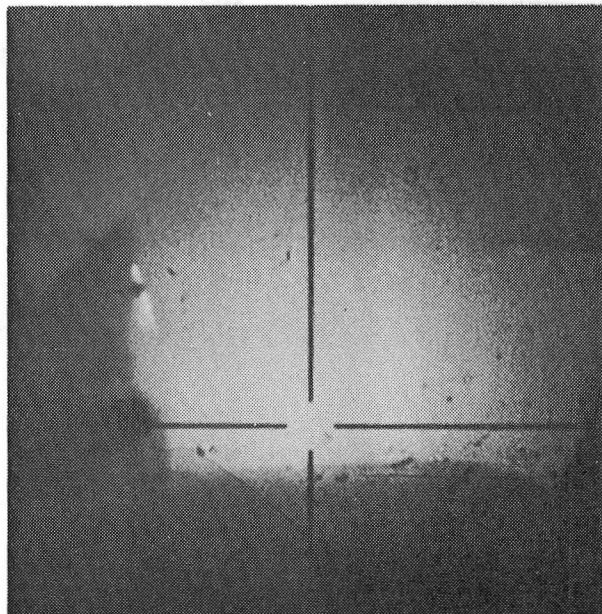


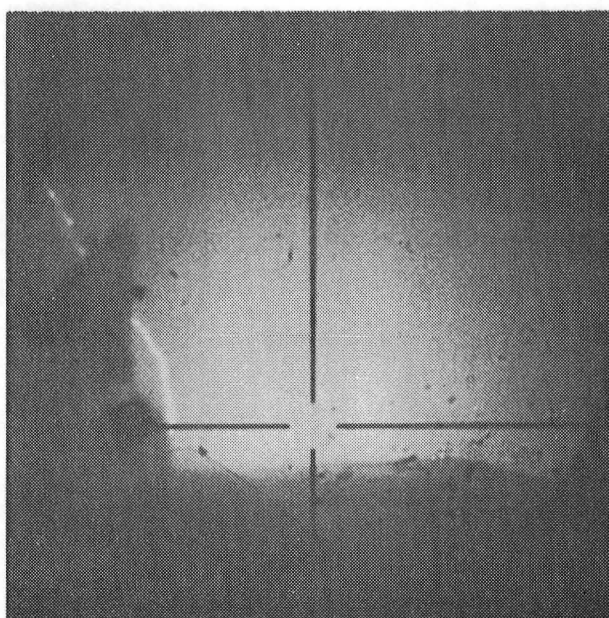
Figure 29. - Strike 10, Flight 82-017, forward camera.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 30. - Strike 10, Flight 82-017, aft camera.

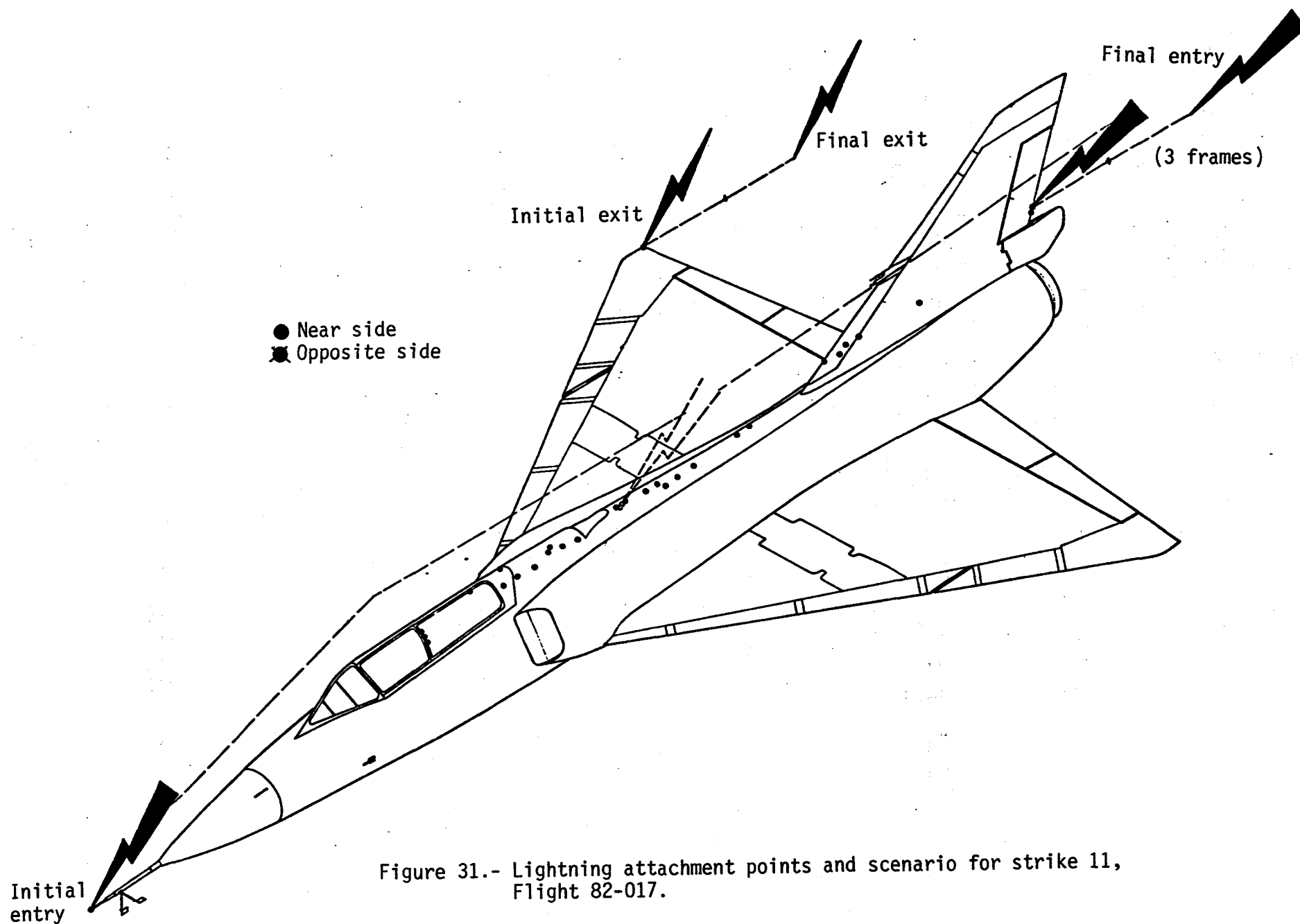


Figure 31.- Lightning attachment points and scenario for strike 11, Flight 82-017.

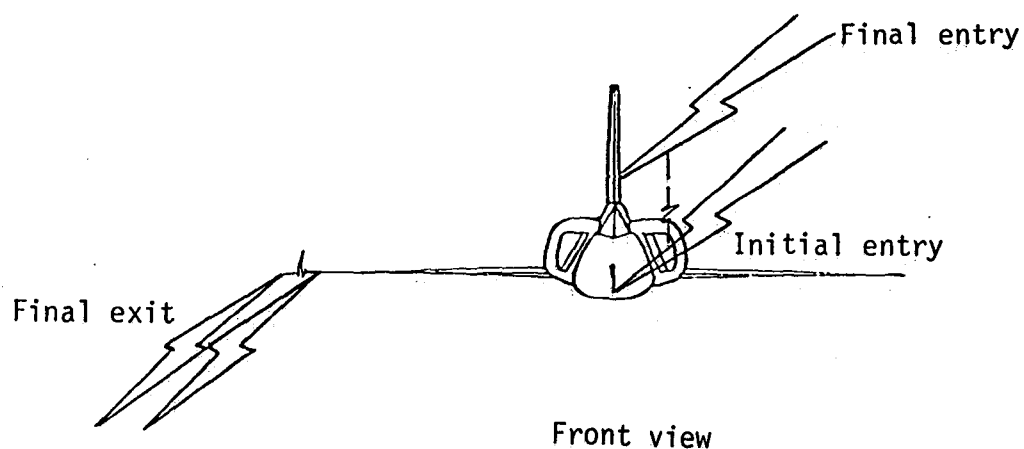
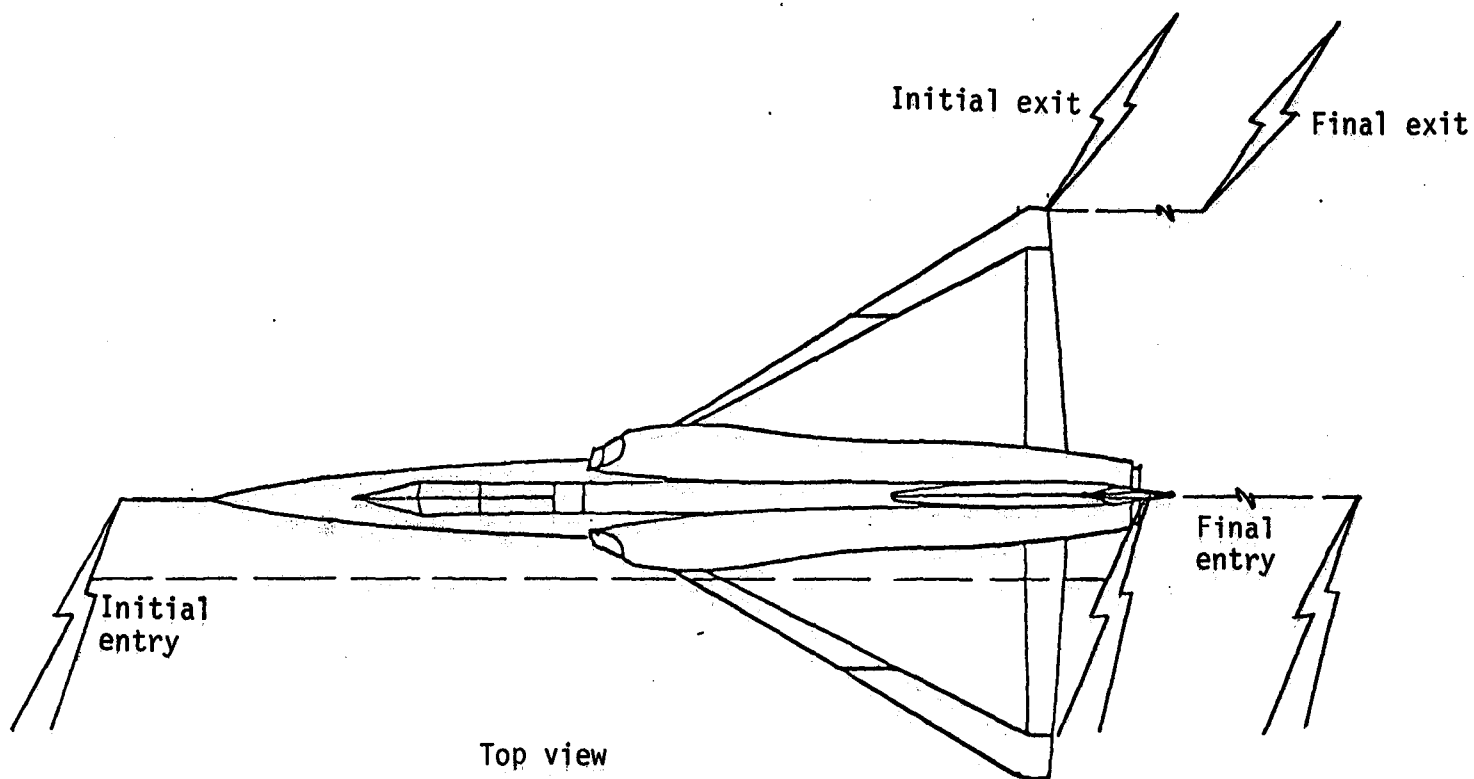
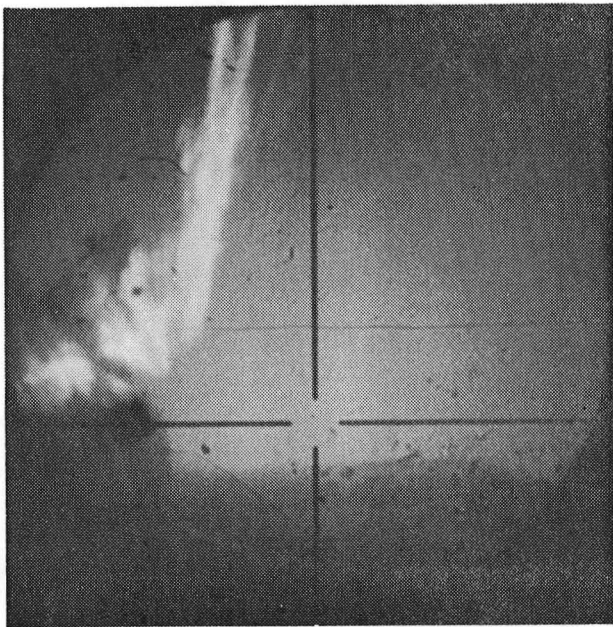
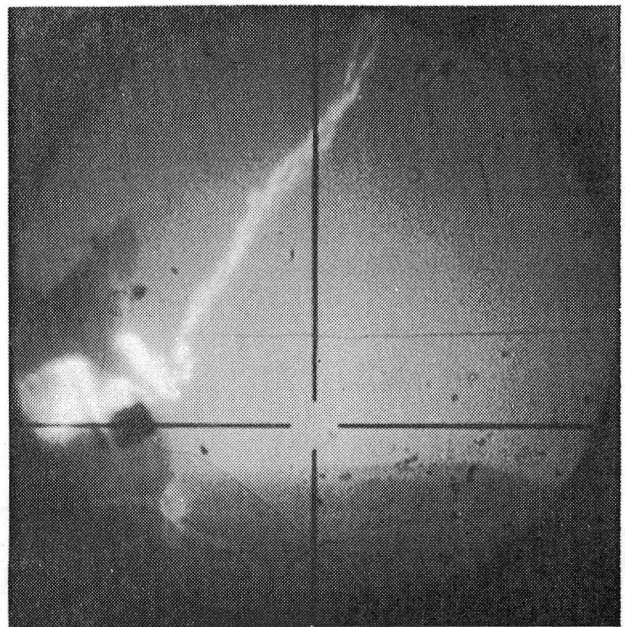


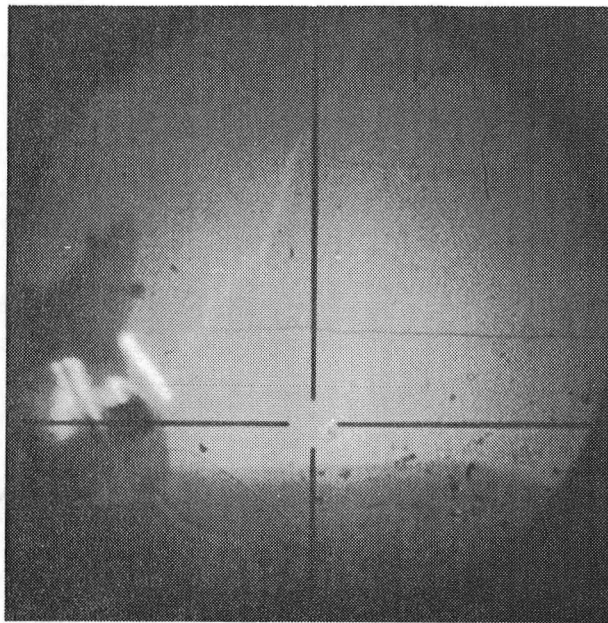
Figure 32.- Lightning attachment point scenario for strike 11,
Flight 82-017.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 33. - Strike 11, Flight 82-017, aft camera.

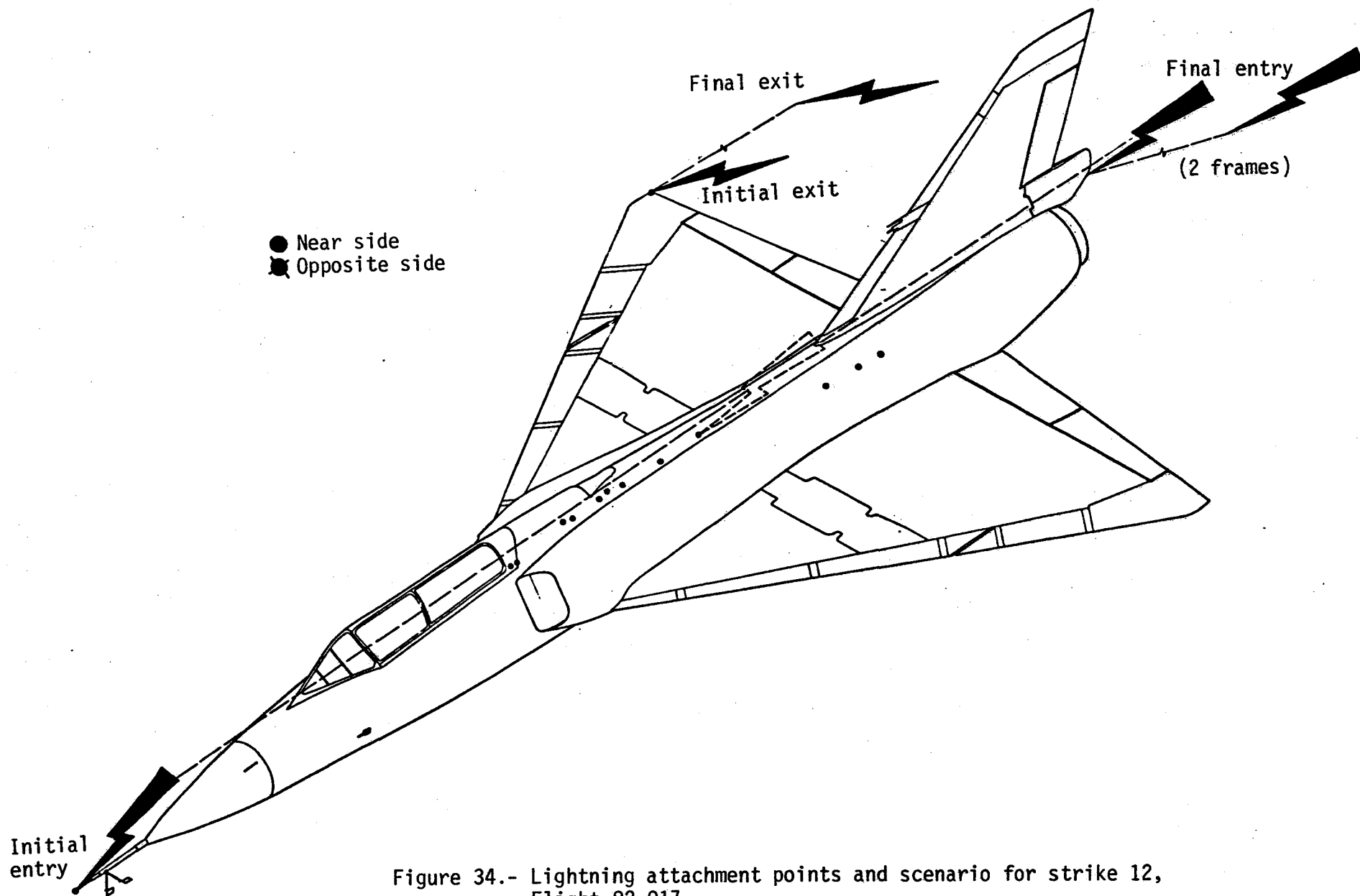


Figure 34.- Lightning attachment points and scenario for strike 12, Flight 82-017.

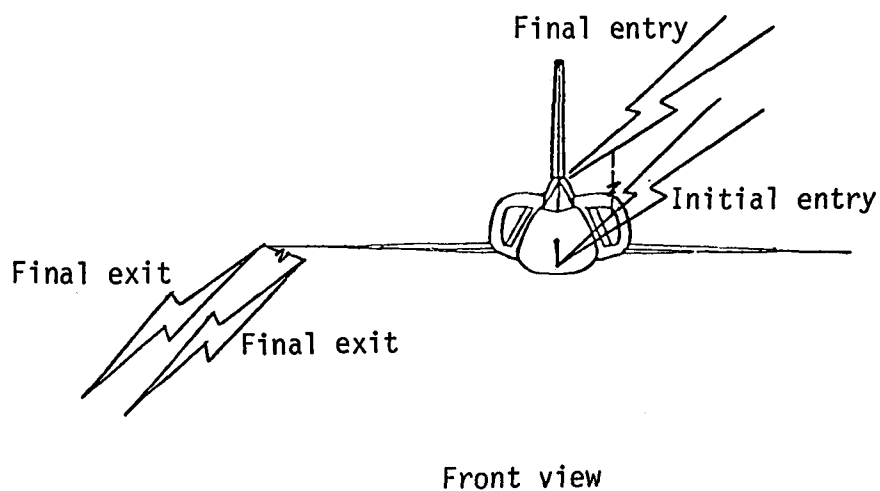
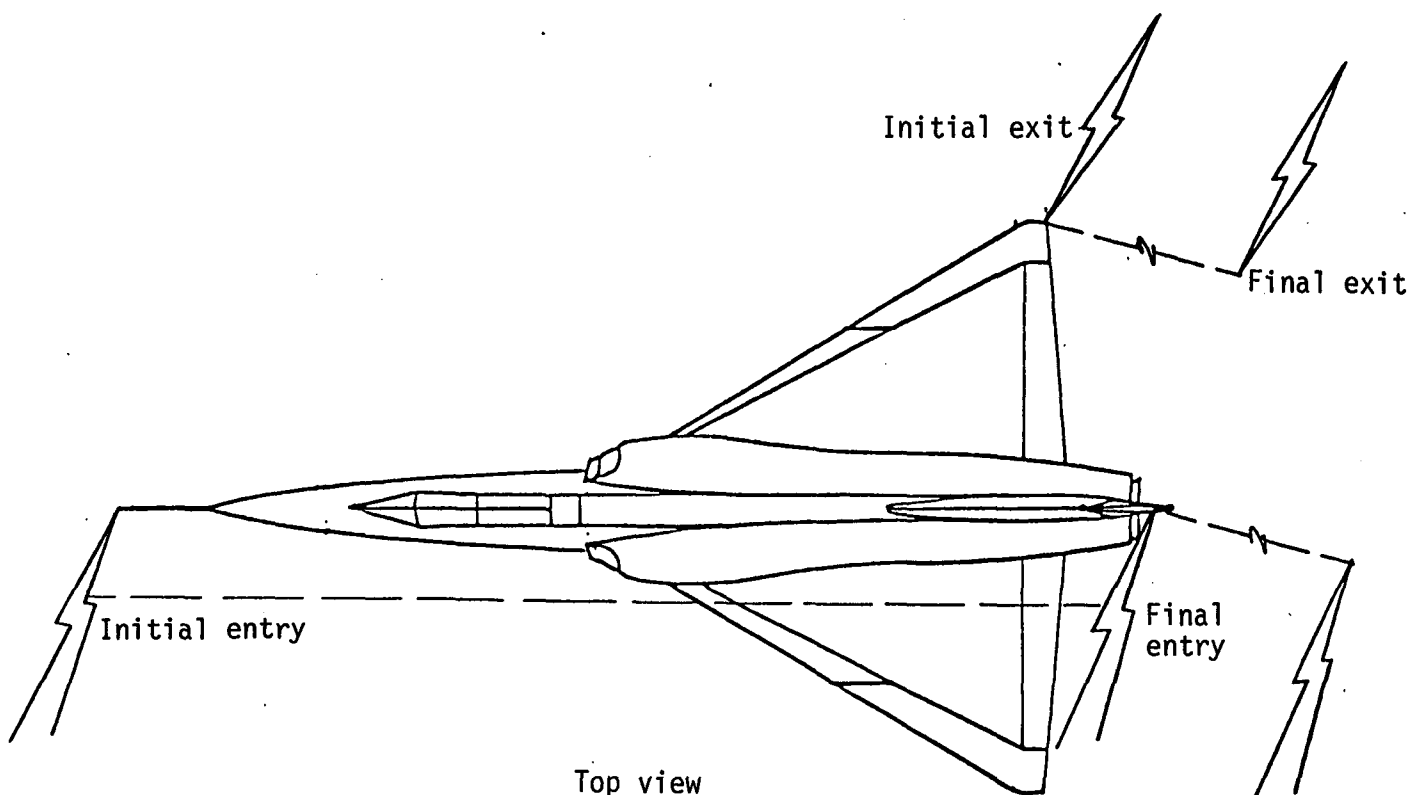
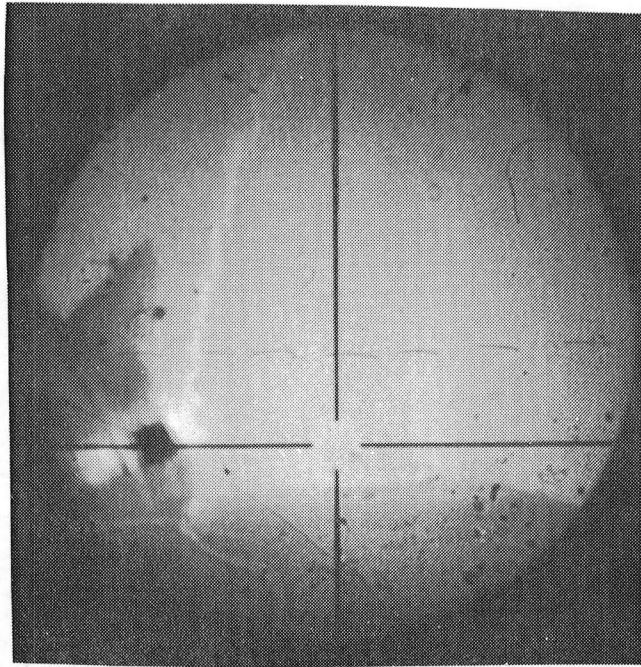
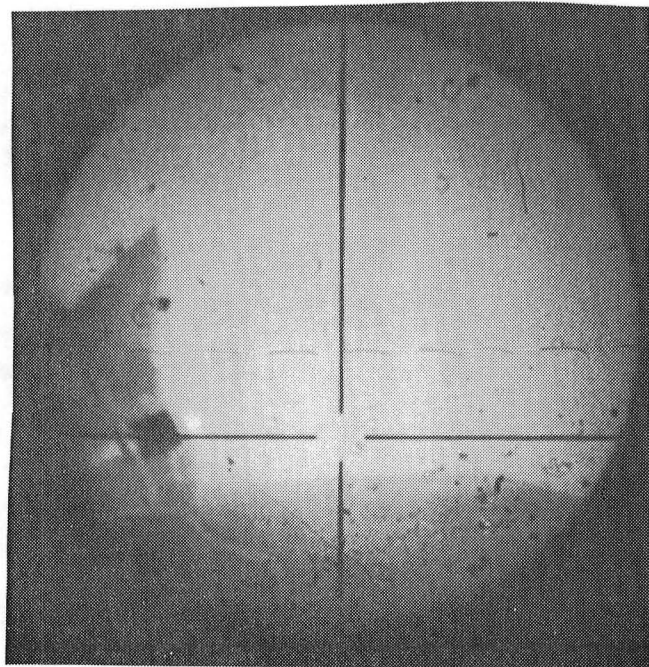


Figure 35.- Lightning attachment point scenario for strike 12, Flight 82-017.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 36. - Strike 12, Flight 82-017, aft camera.

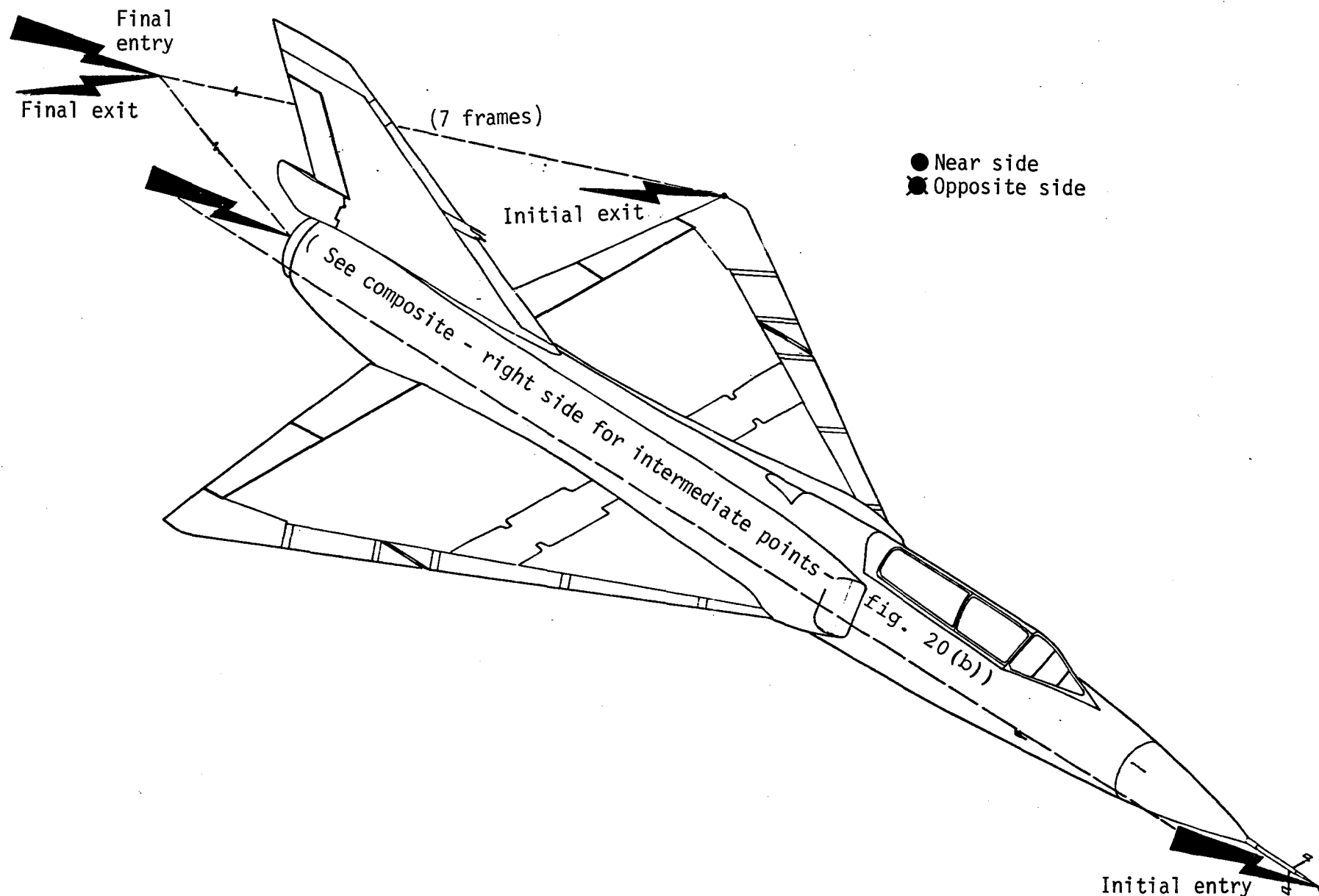
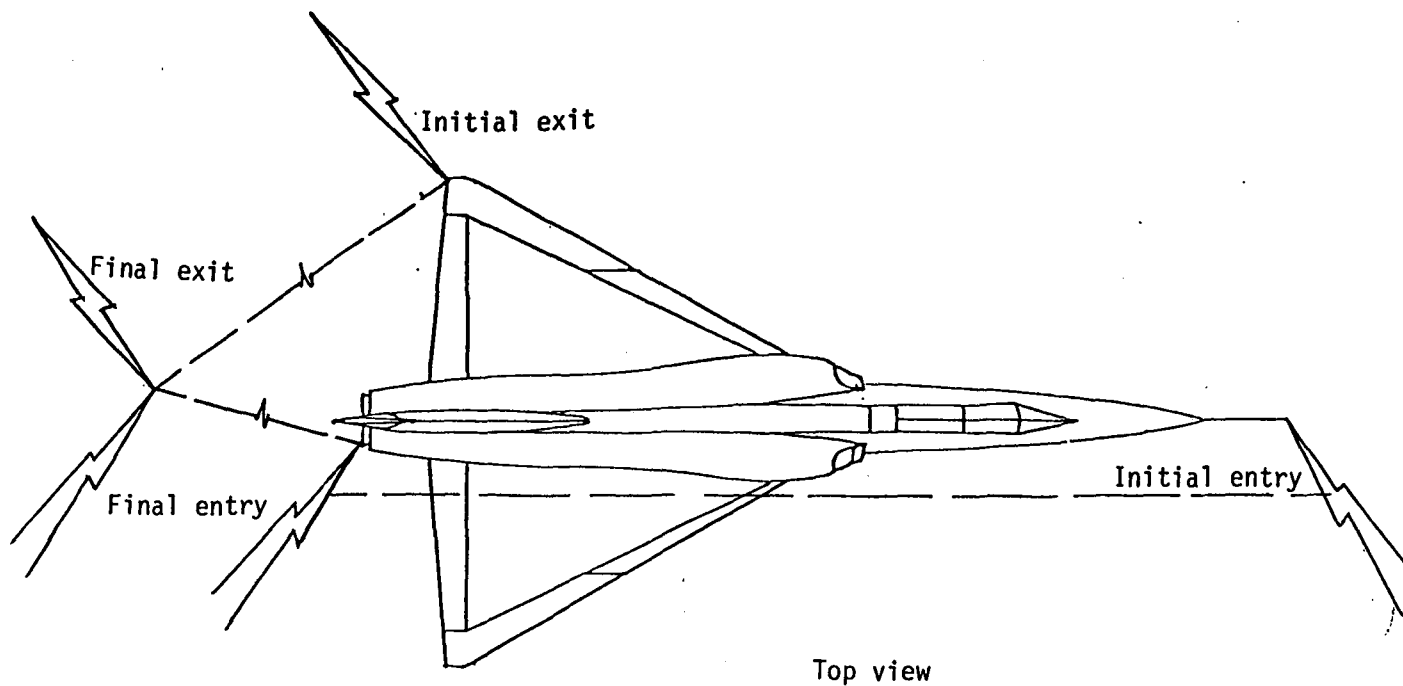
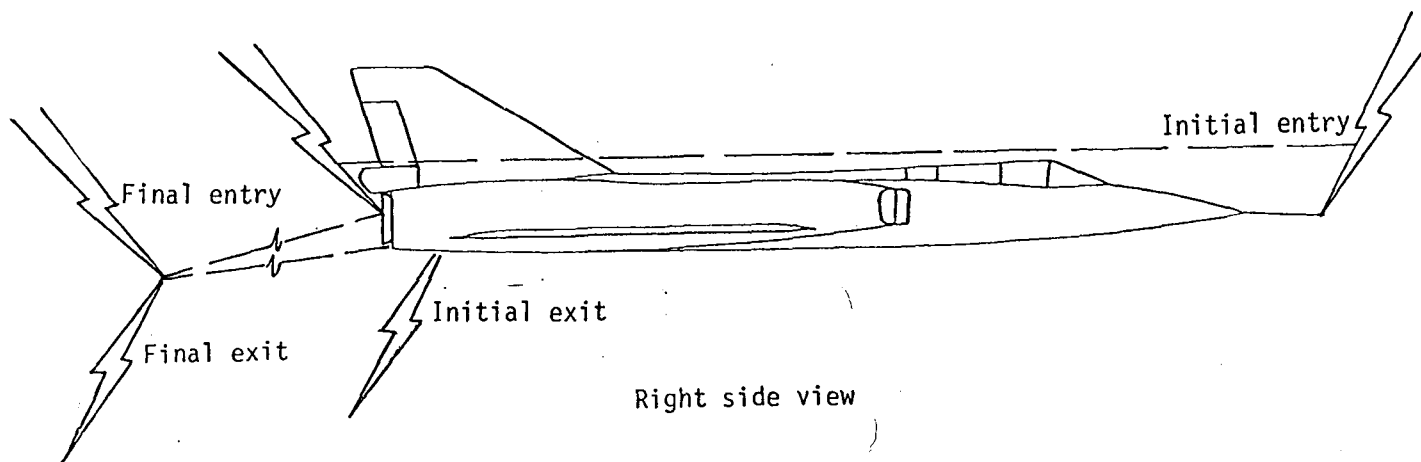


Figure 37.- Lightning attachment points and scenario for strike 13, Flight 82-017.



Top view



Right side view

Figure 38.- Lightning attachment point scenario for strike 13, Flight 82-017.

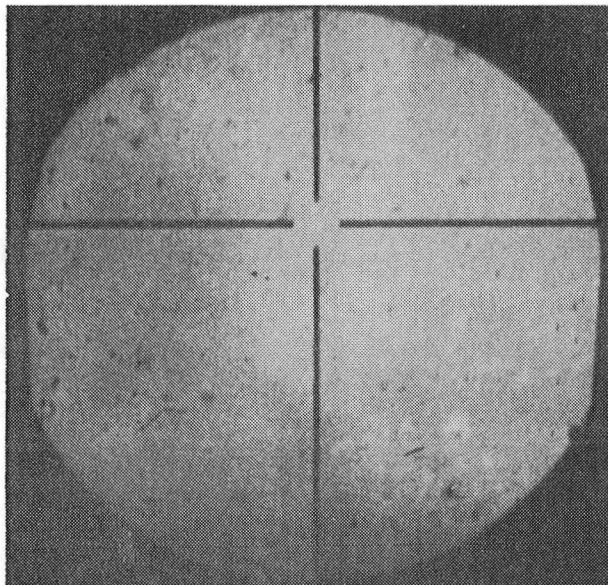
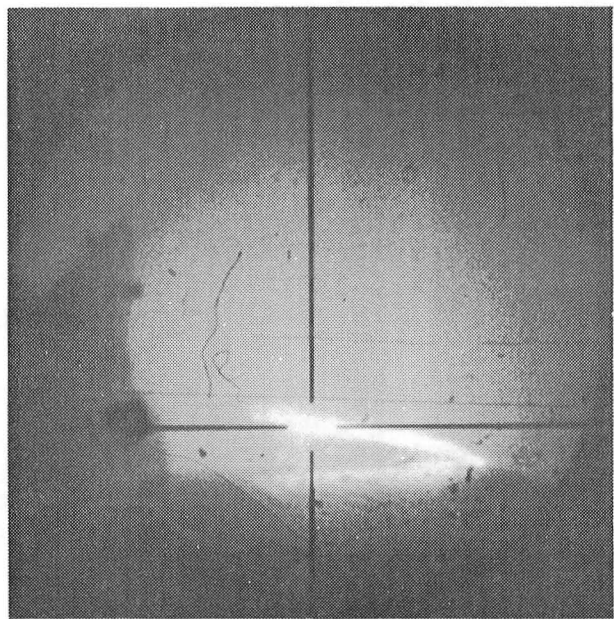


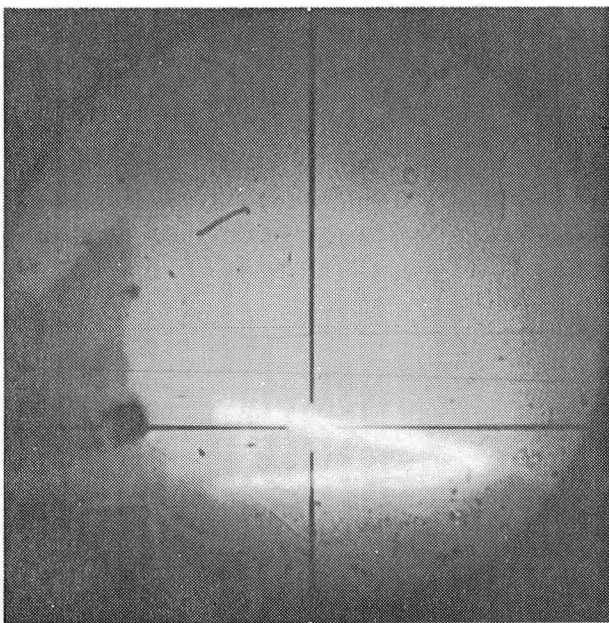
Figure 39. - Strike 13, Flight 82-017, forward camera.



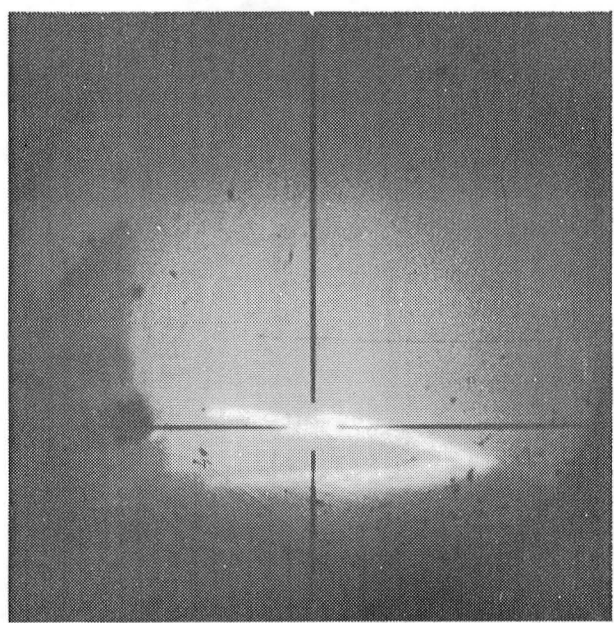
(a) Frame 1 of 7.



(b) Frame 2 of 7.

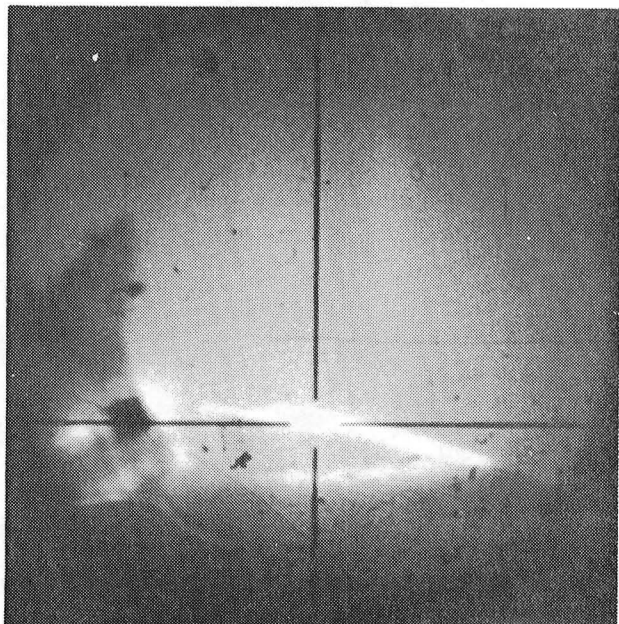


(c) Frame 3 of 7.



(d) Frame 4 of 7.

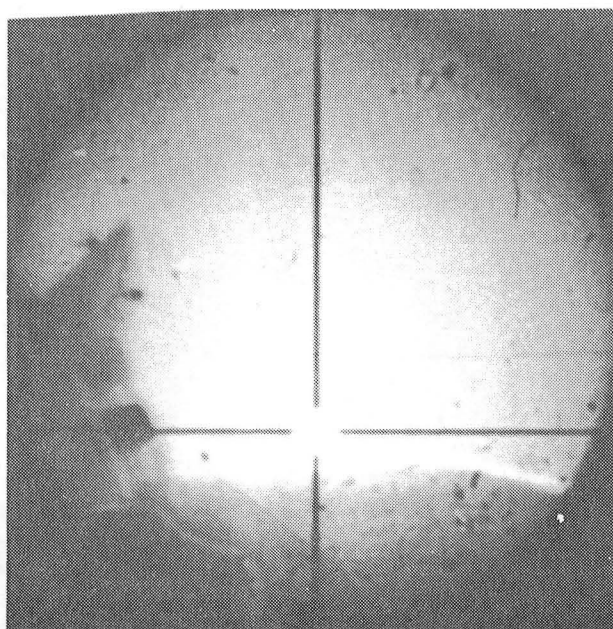
Figure 40. - Strike 13, Flight 82-017, aft camera.



(e) Frame 5 of 7.



(f) Frame 6 of 7.



(g) Frame 7 of 7.

Figure 40. - Concluded.

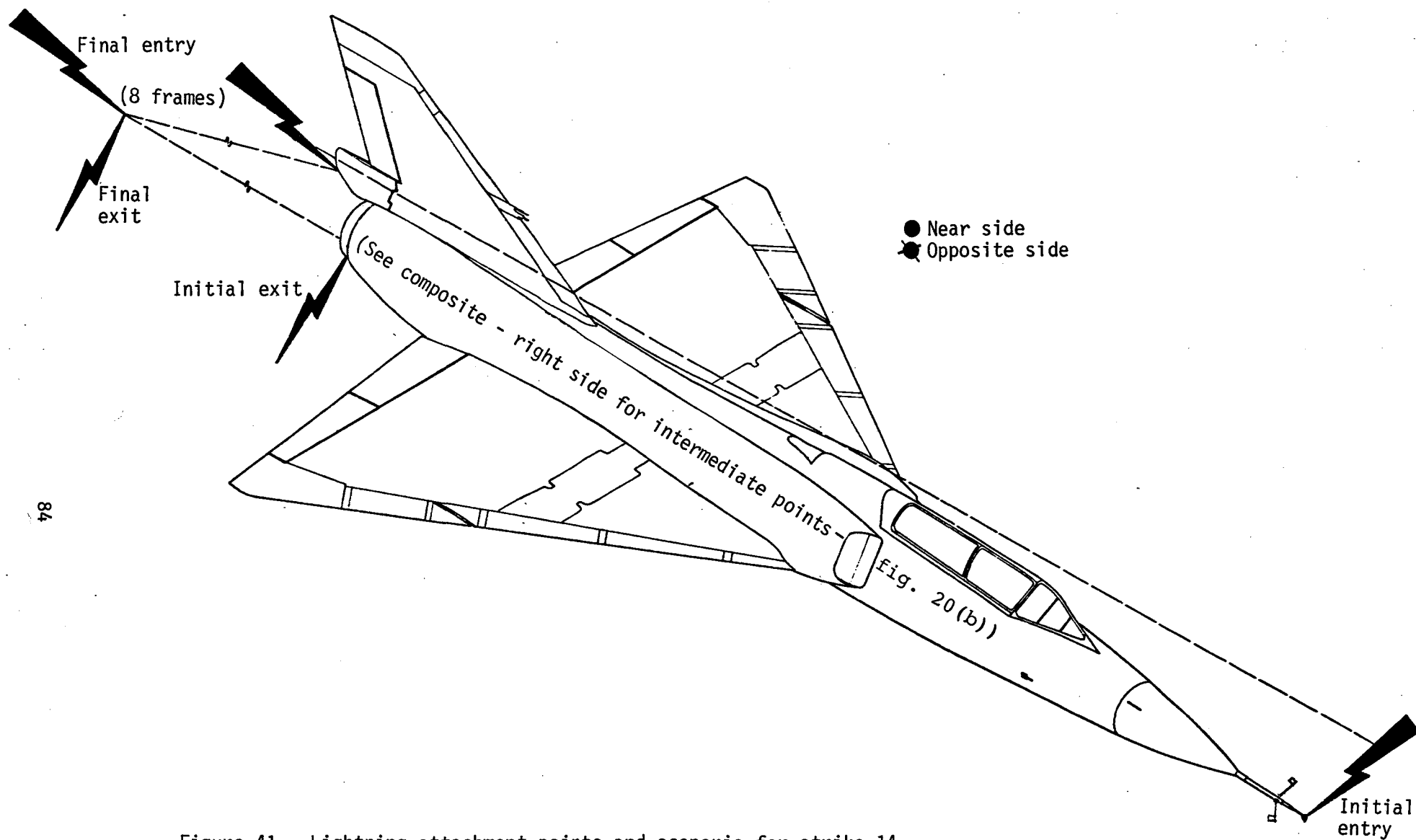


Figure 41.- Lightning attachment points and scenario for strike 14, Fight 82-017.

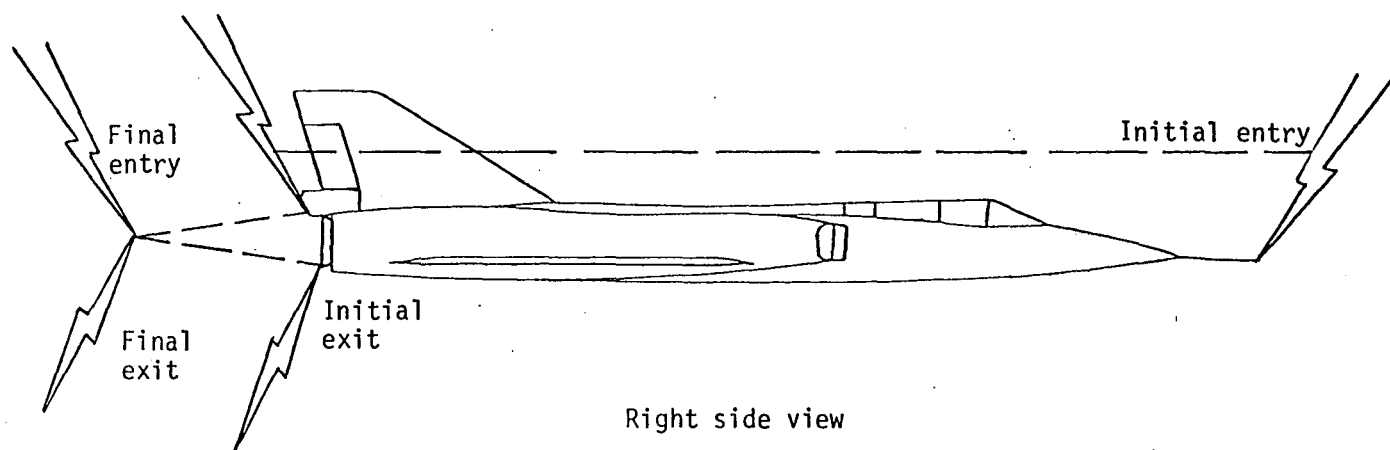
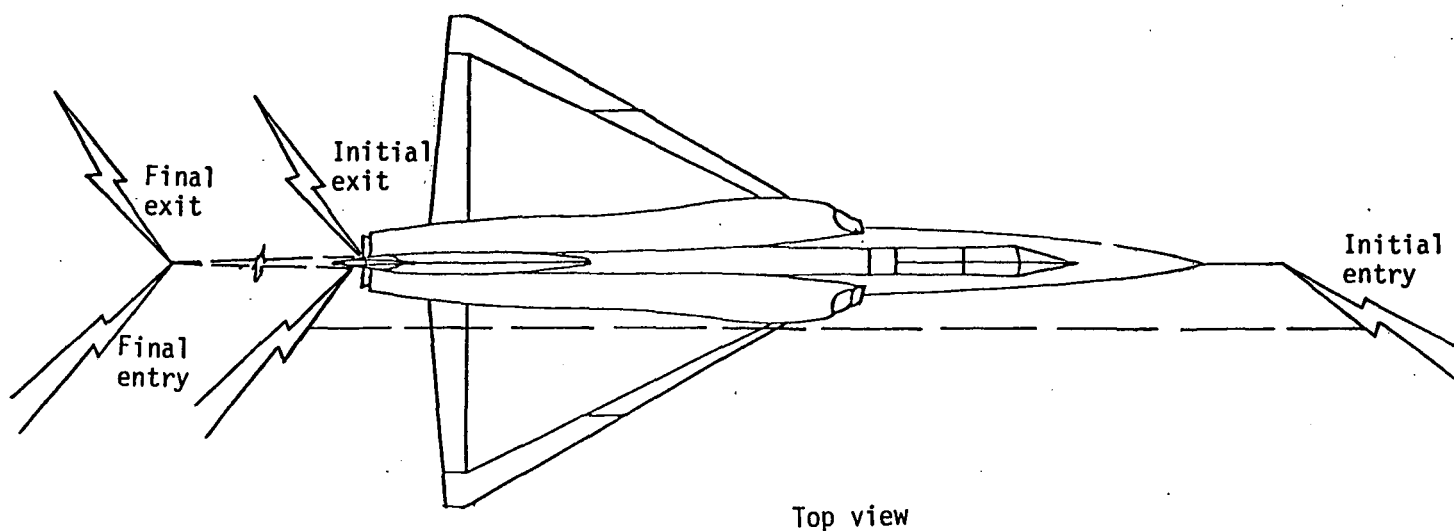


Figure 42.- Lightning attachment point scenario for strike 14,
Flight 82-017.

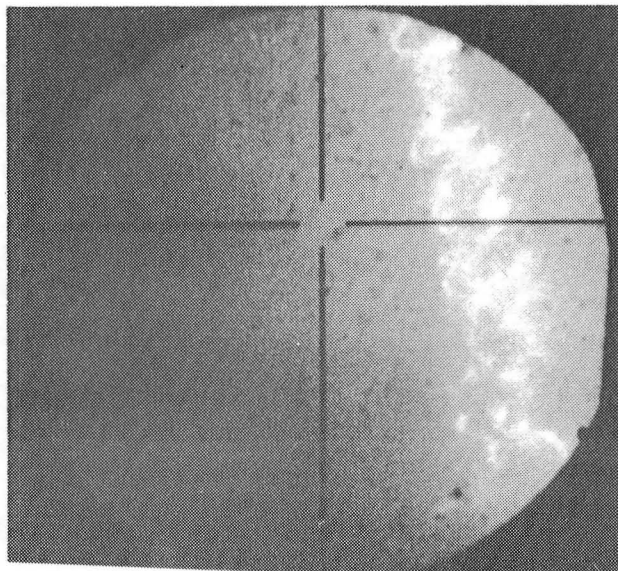
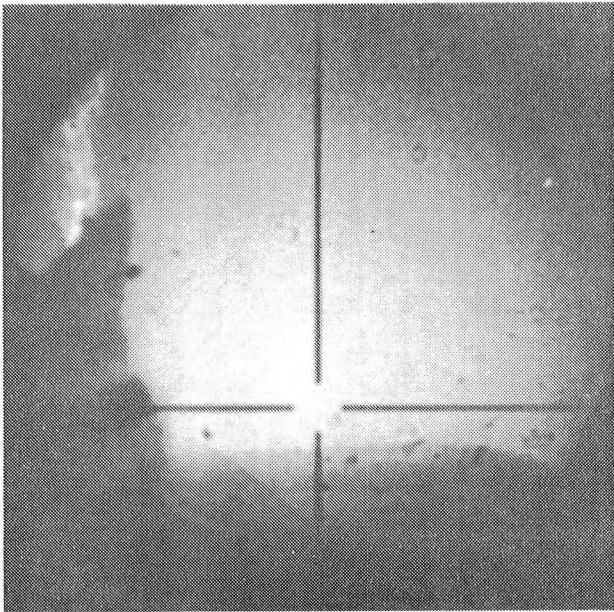
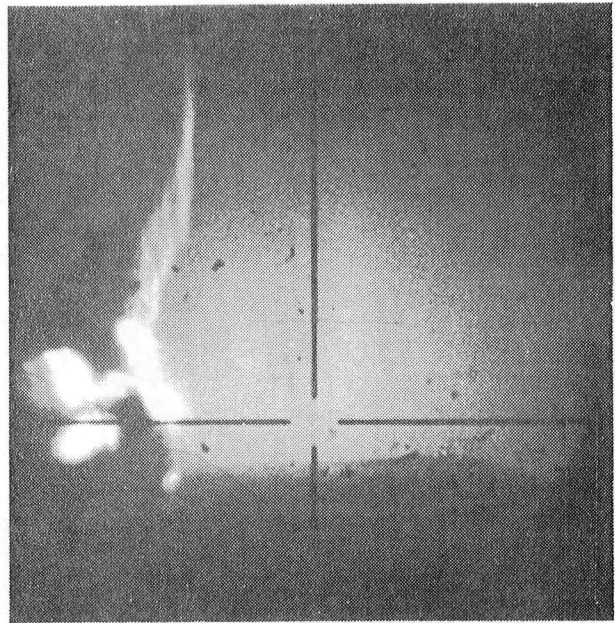


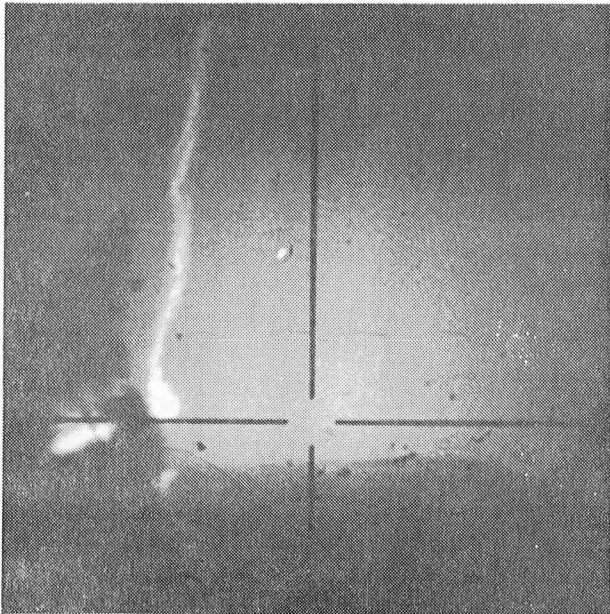
Figure 43. - Strike 14, Flight 82-017, forward camera.



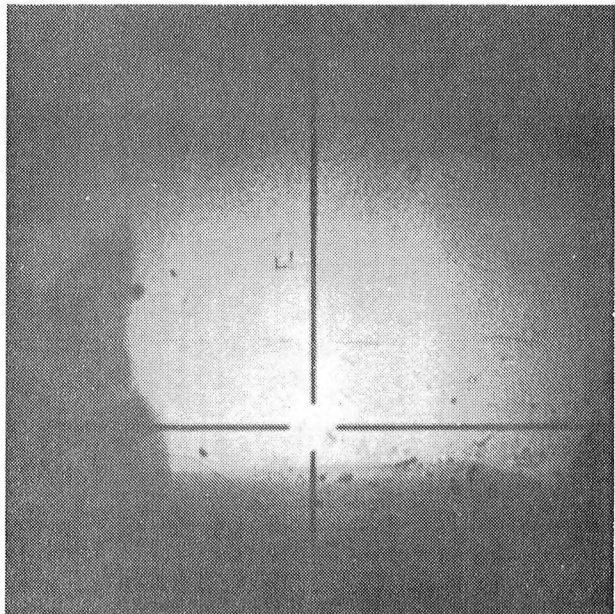
(a) Frame 1 of 8.



(b) Frame 2 of 8.

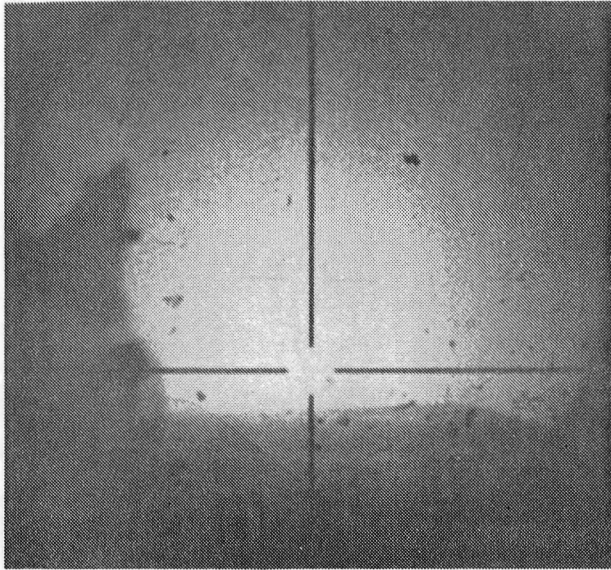


(c) Frame 3 of 8.

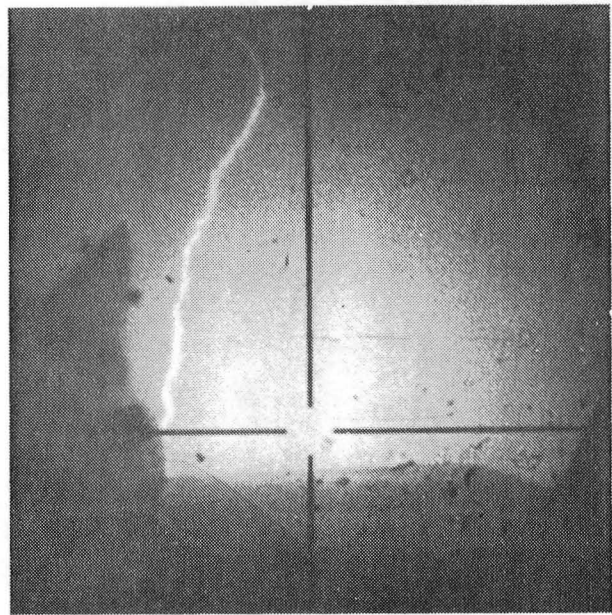


(d) Frame 4 of 8.

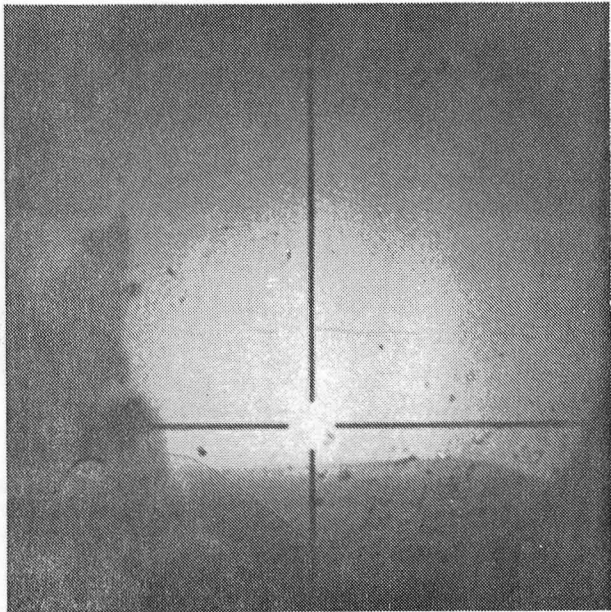
Figure 44. - Strike 14, Flight 82-017, aft camera.



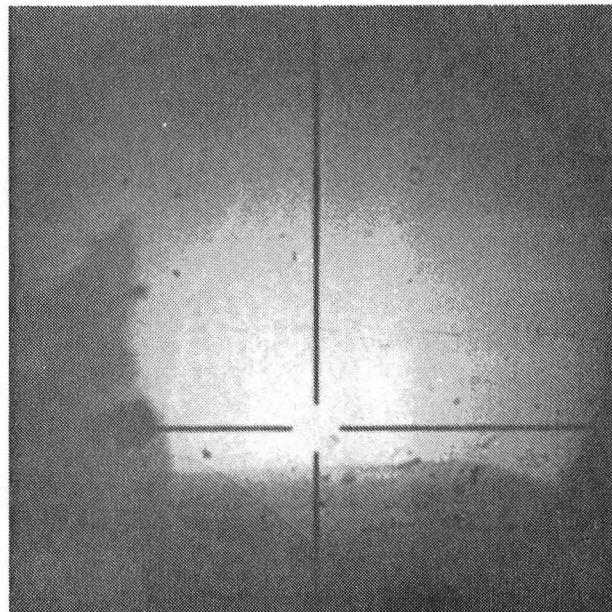
(e) Frame 5 of 8.



(f) Frame 6 of 8.



(g) Frame 7 of 8.



(h) Frame 8 of 8.

Figure 44. - Concluded.

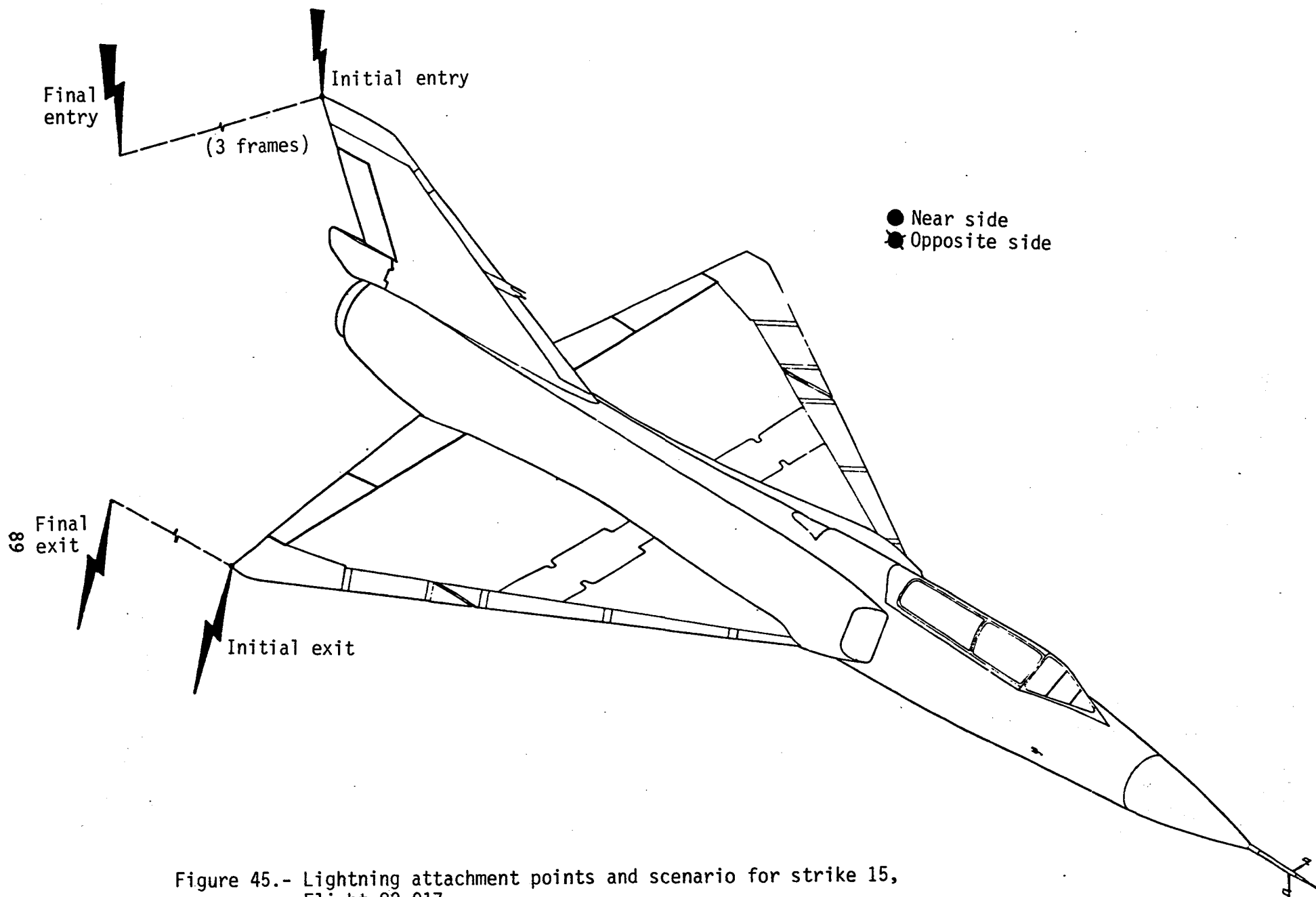


Figure 45.- Lightning attachment points and scenario for strike 15, Flight 82-017.

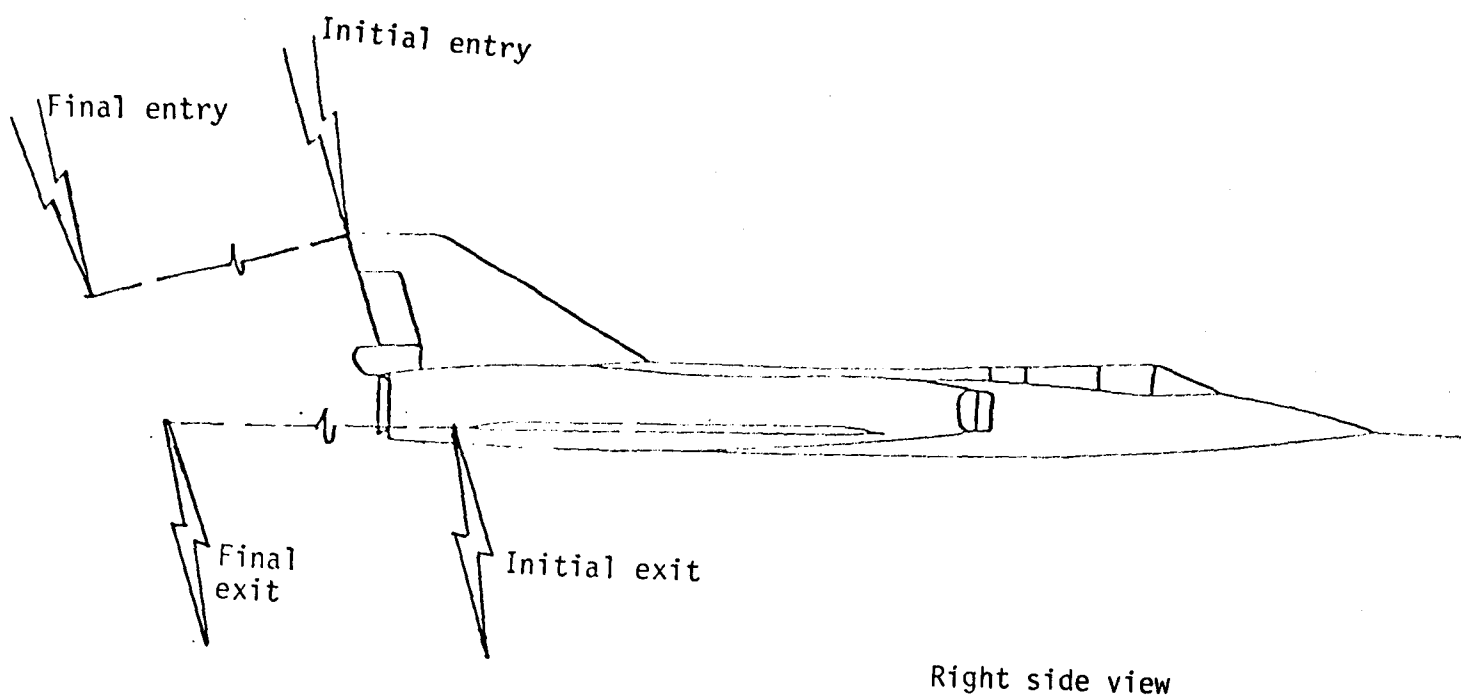
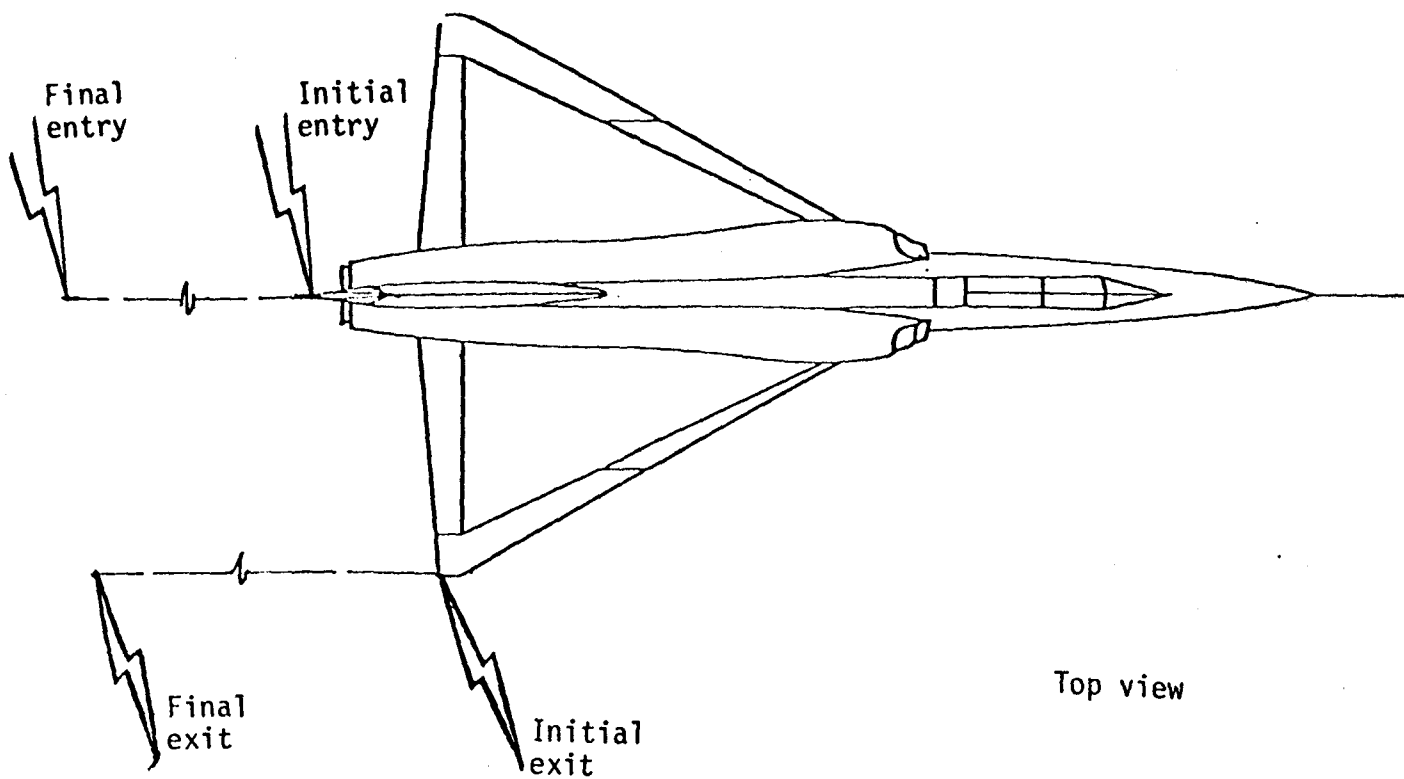
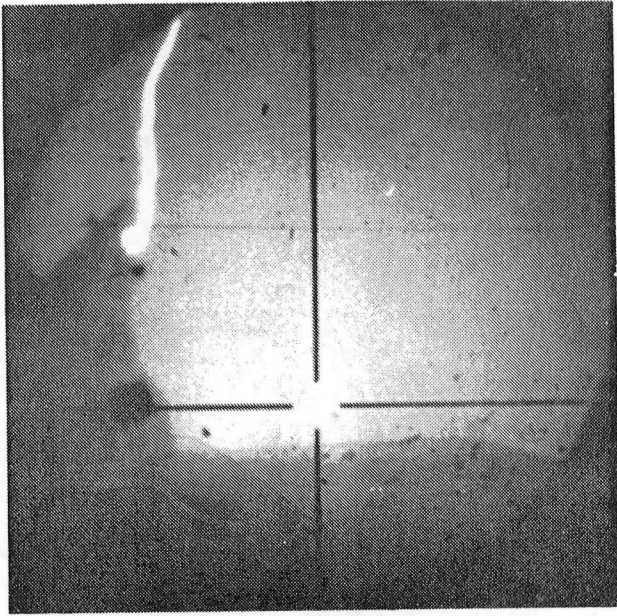
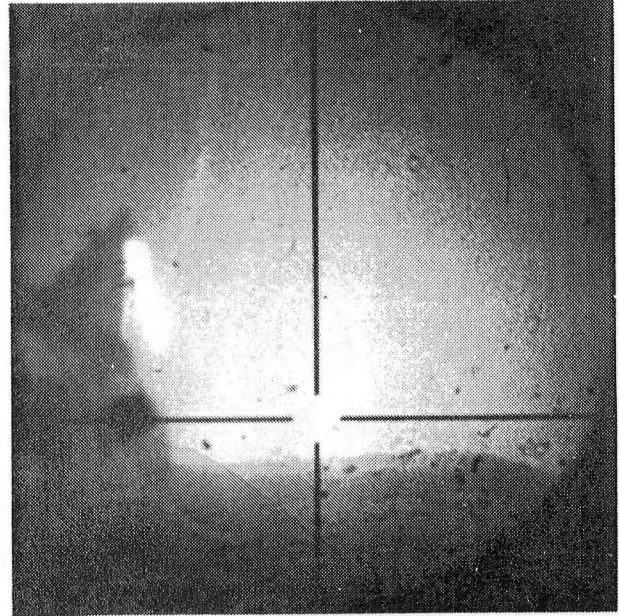


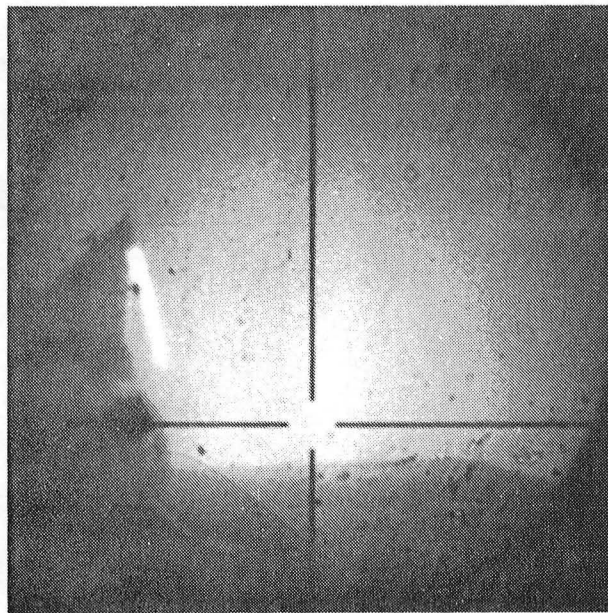
Figure 46.- Lightning attachment point scenario for strike 15, Flight 82-017.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 47. - Strike 15, Flight 82-017, aft camera.

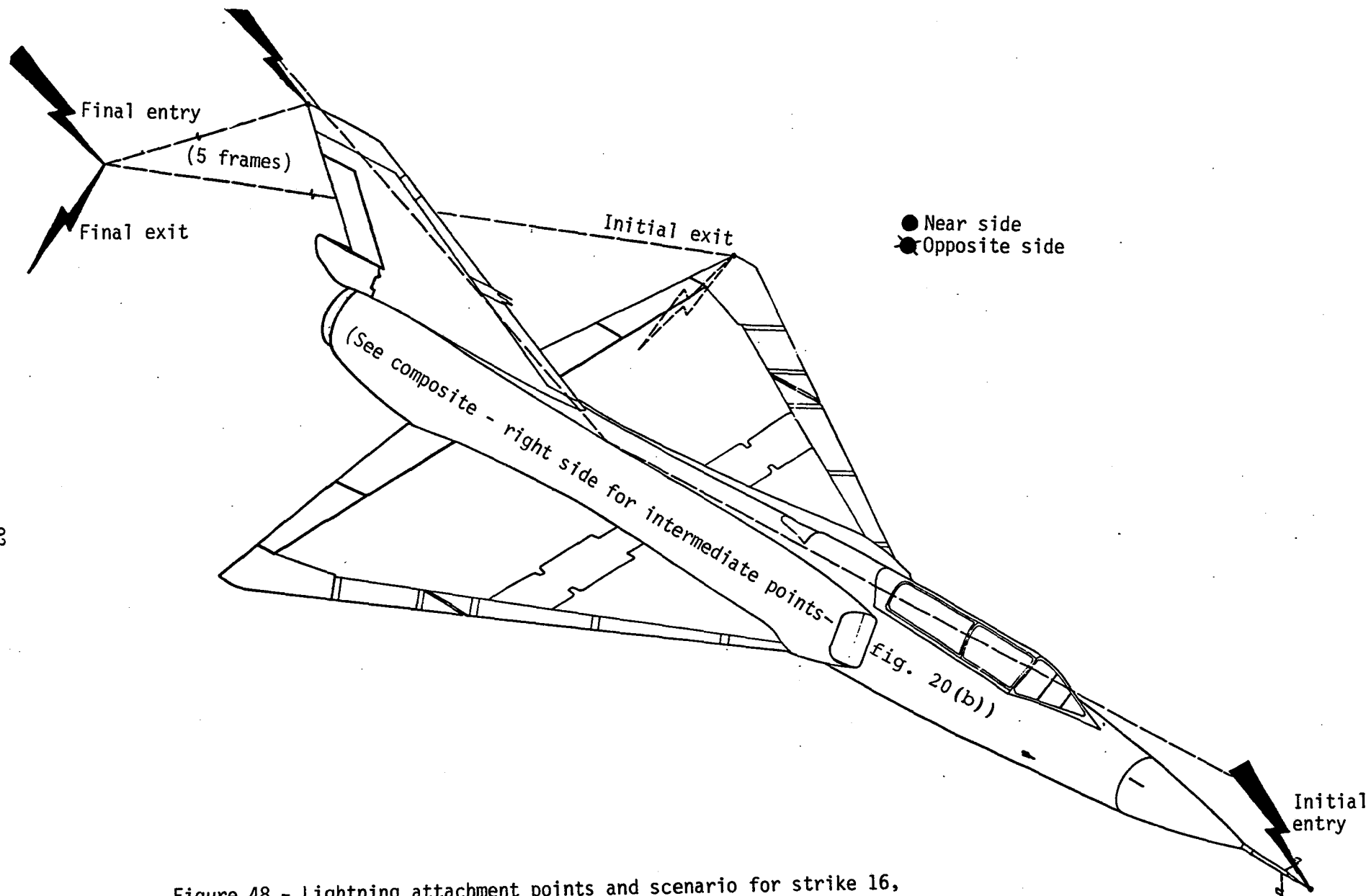


Figure 48.- Lightning attachment points and scenario for strike 16, flight 82-017.

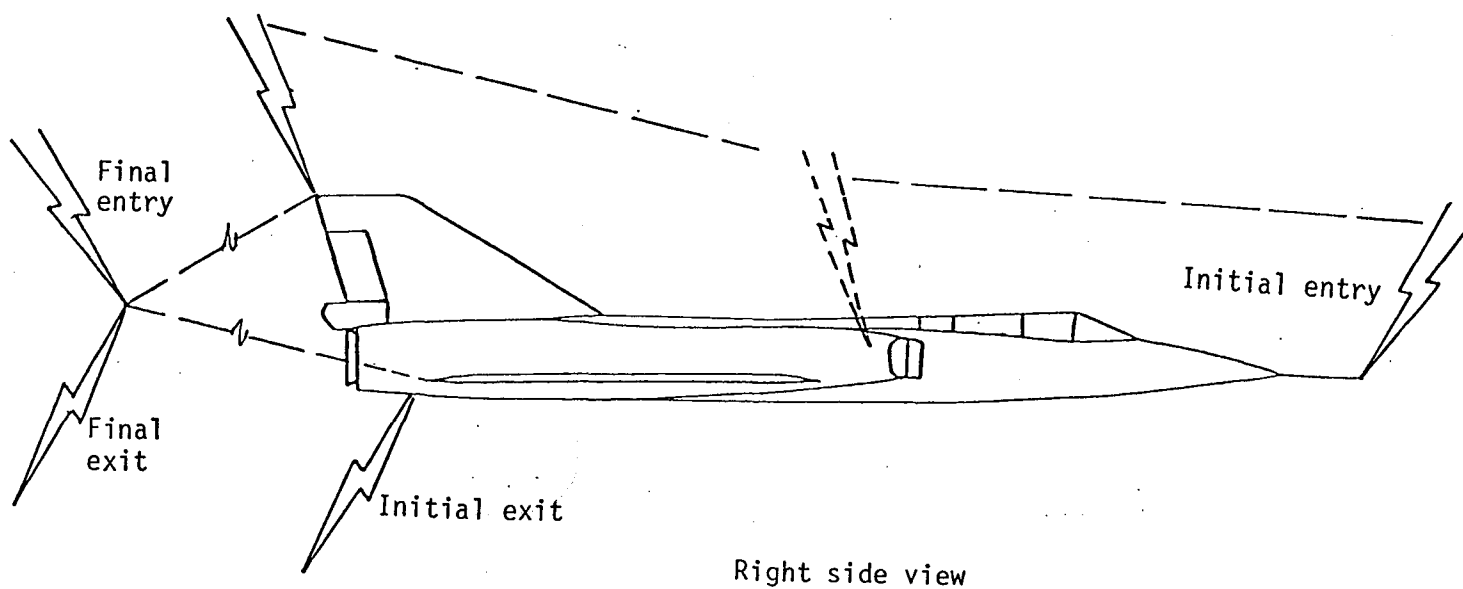
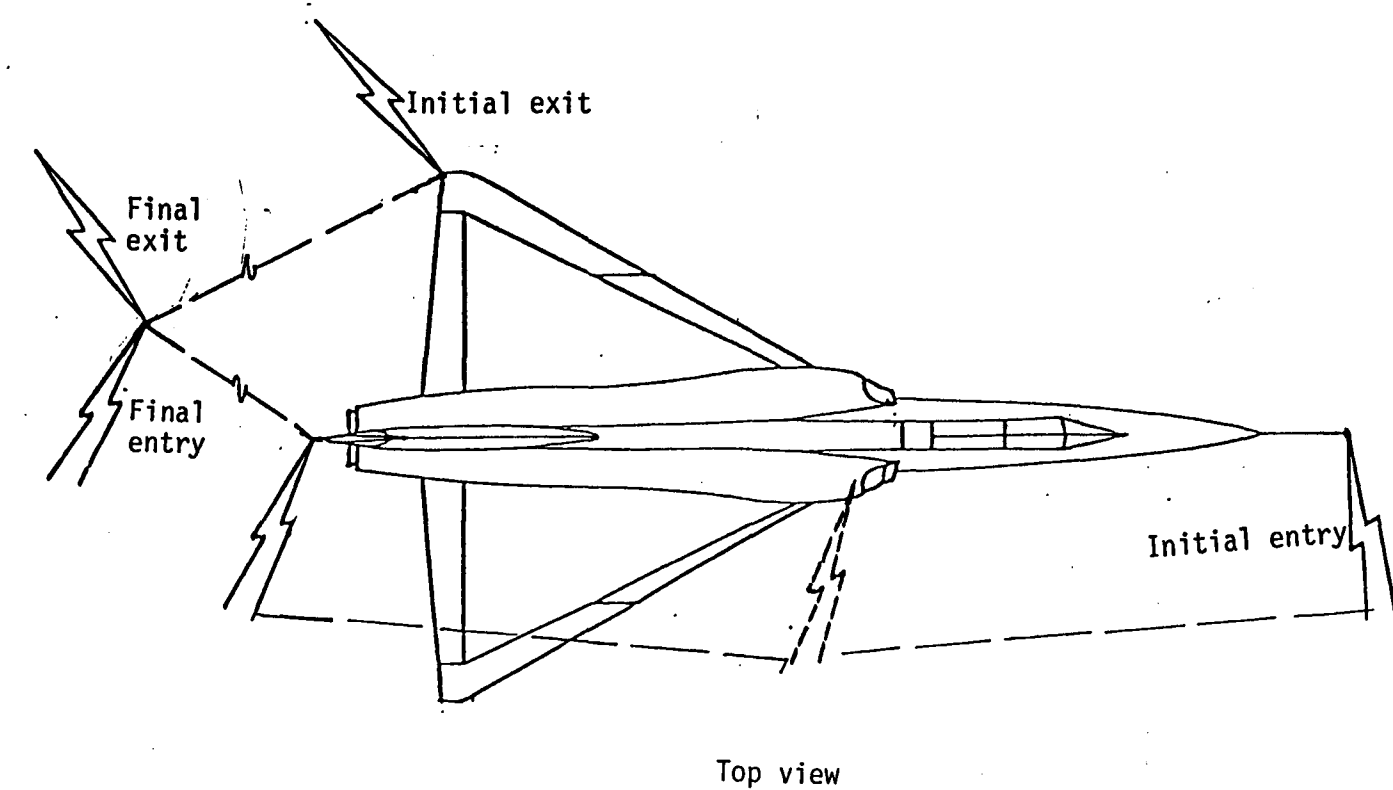
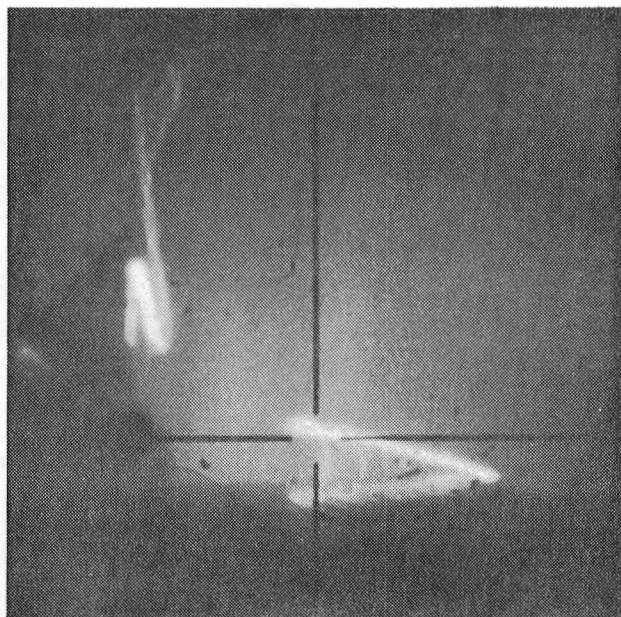
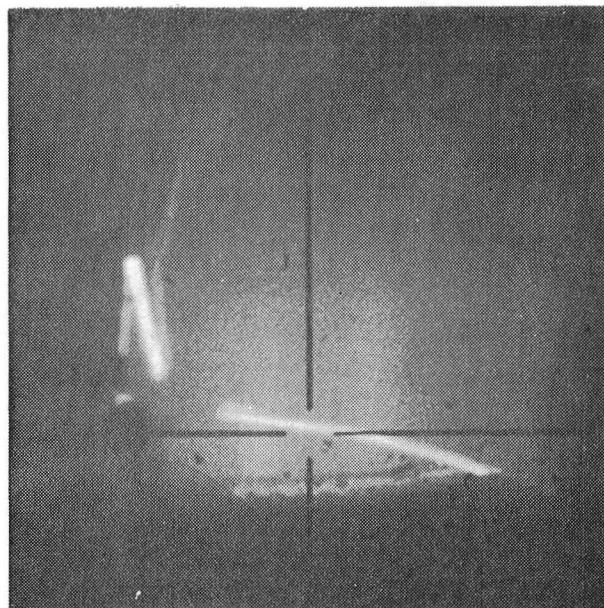


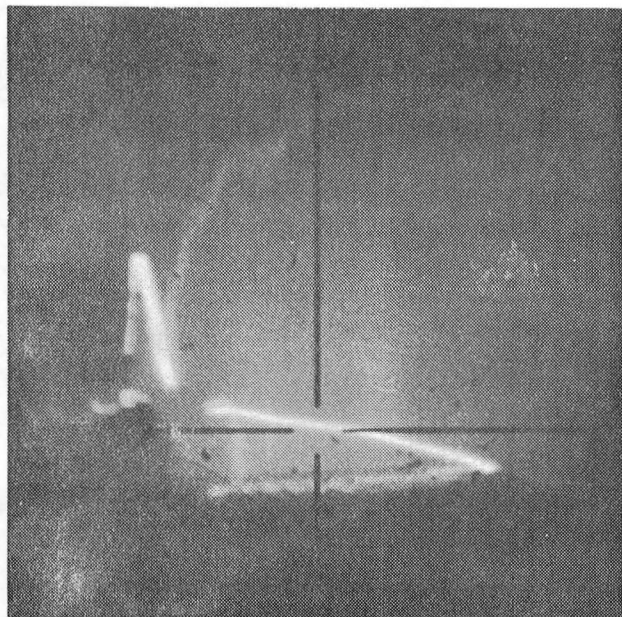
Figure 49.- Lightning attachment point scenario for strike 16, Flight 82-017.



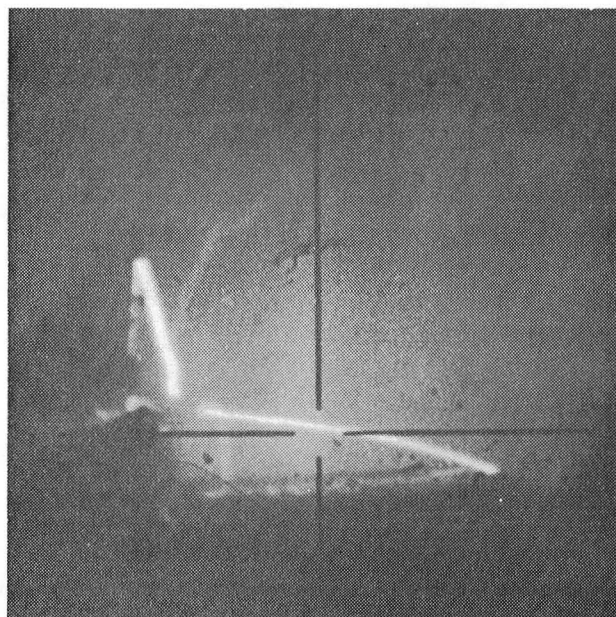
(a) Frame 1 of 10.



(b) Frame 2 of 10.

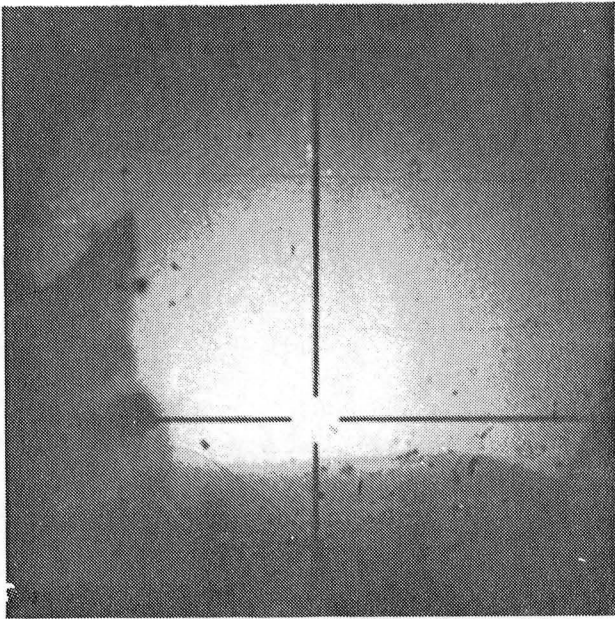


(c) Frame 3 of 10.

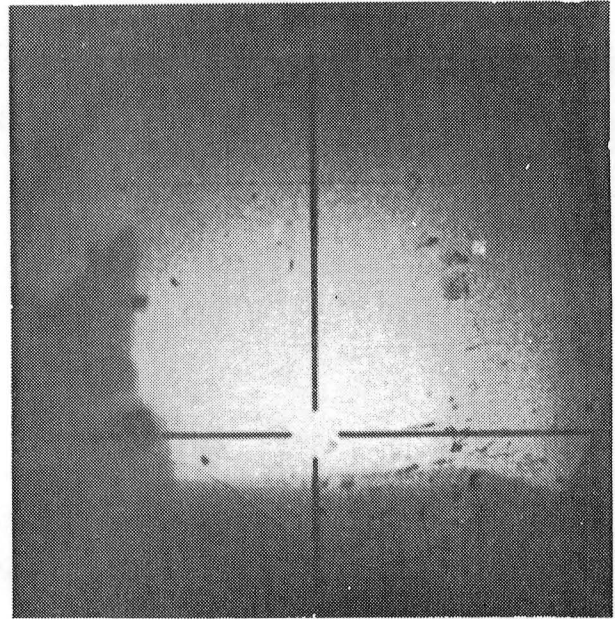


(d) Frame 4 of 10.

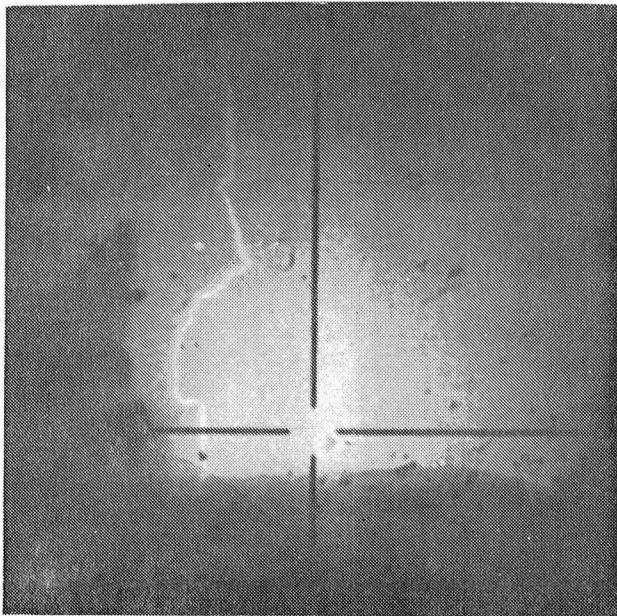
Figure 50. - Strike 16, Flight 82-017, aft camera.



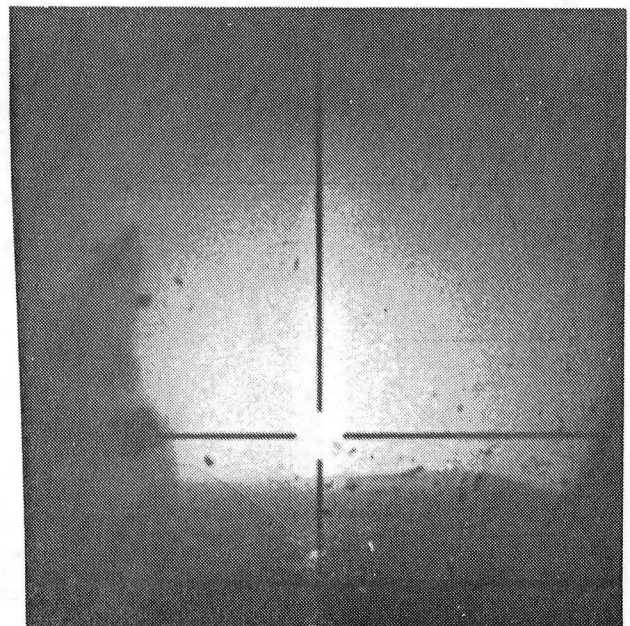
(e) Frame 5 of 10.



(f) Frame 6 of 10.

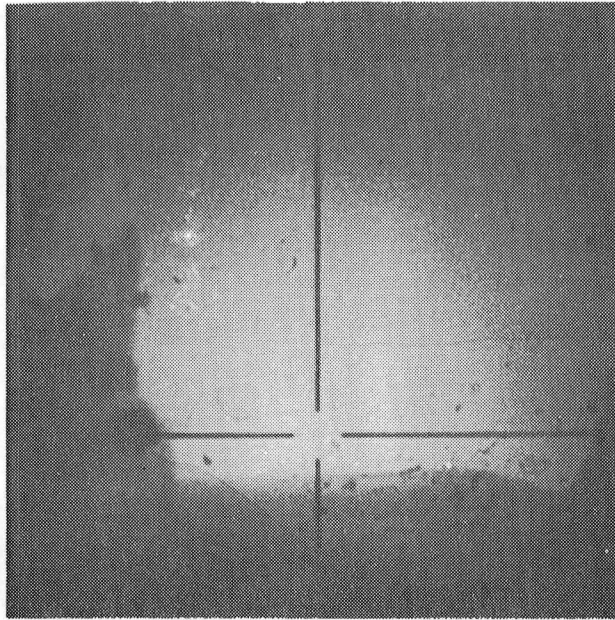


(g) Frame 7 of 10.

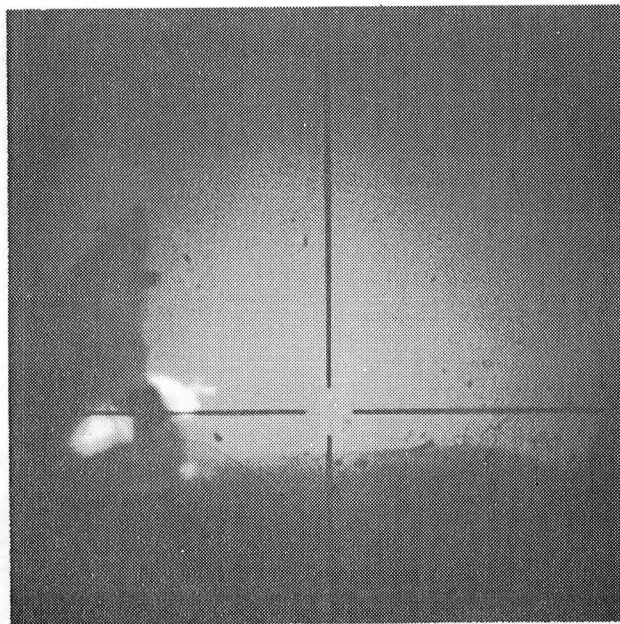


(h) Frame 8 of 10.

Figure 50. - Continued.



(i) Frame 9 of 10.



(j) Frame 10 of 10.

Figure 50. - Concluded.

● Near side
✱ Opposite side

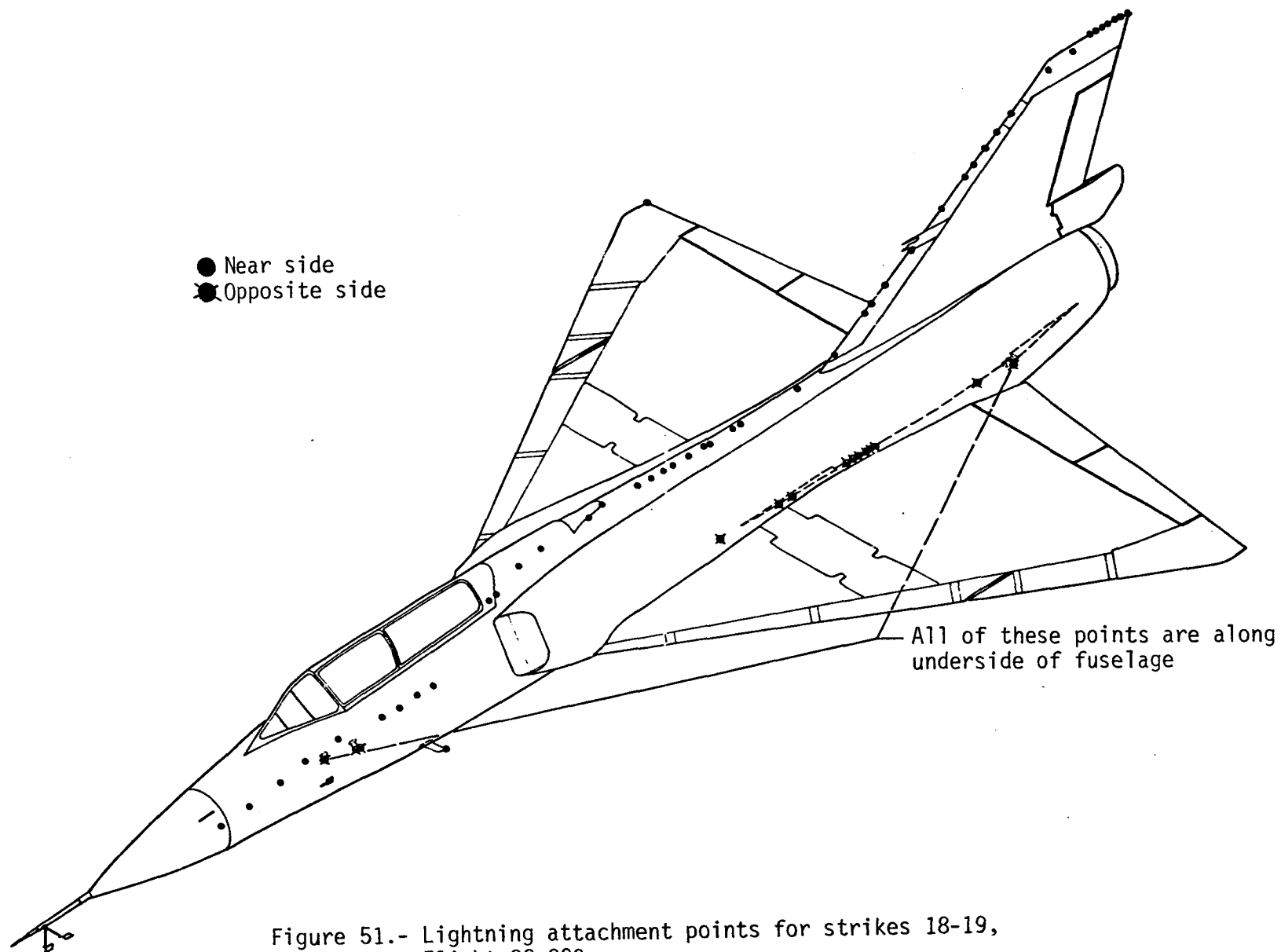


Figure 51.- Lightning attachment points for strikes 18-19,
Flight 82-020.

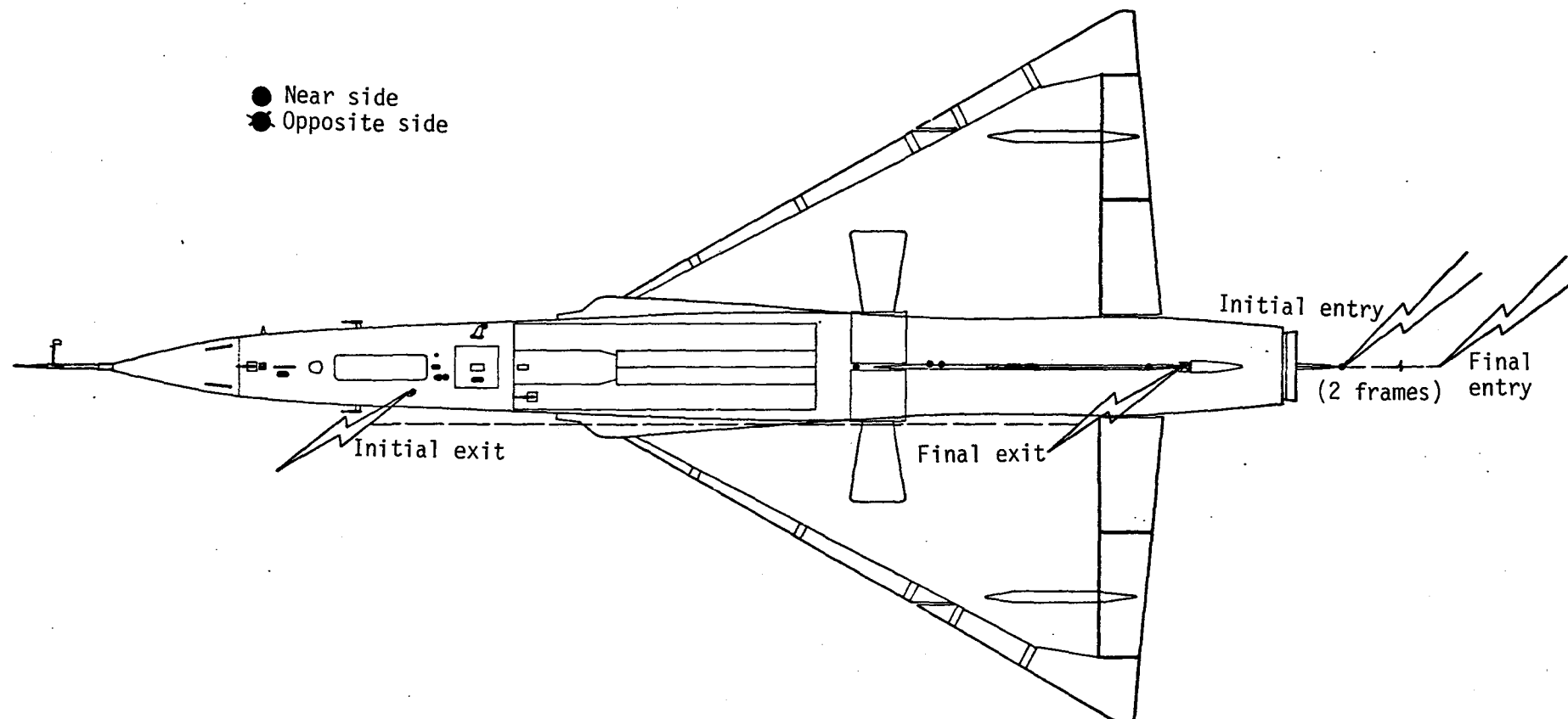


Figure 52.- Lightning attachment points and scenario for strike 18, Flight 82-020.

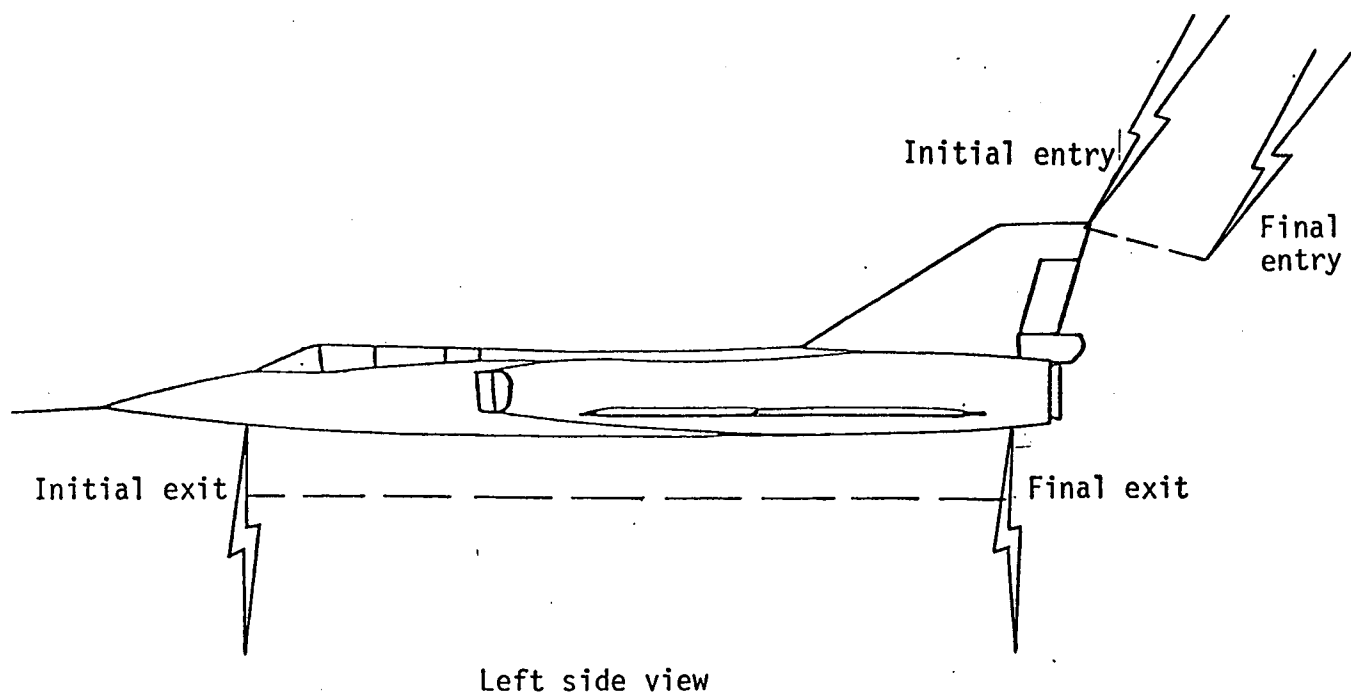
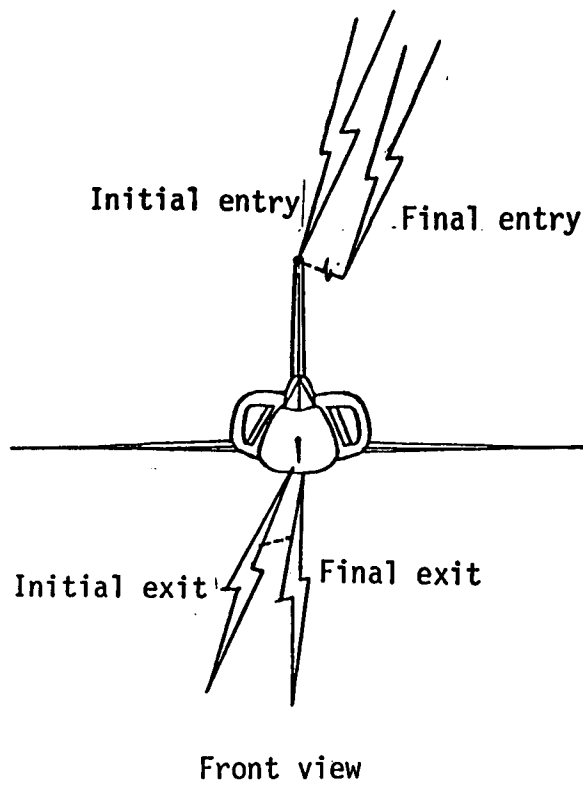
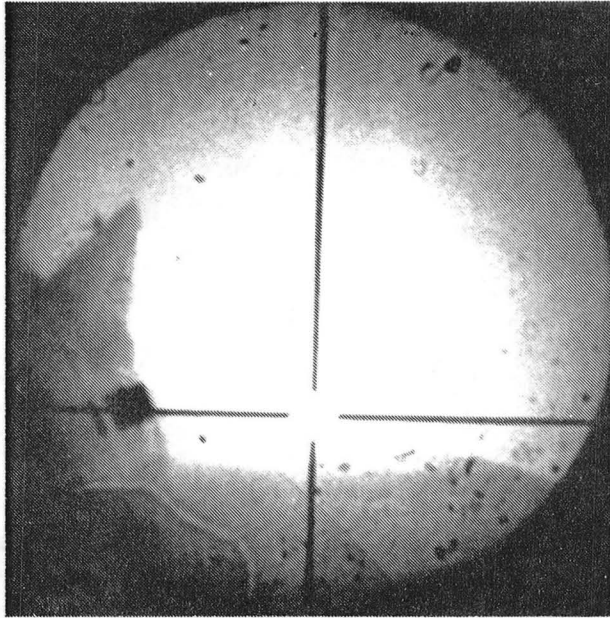
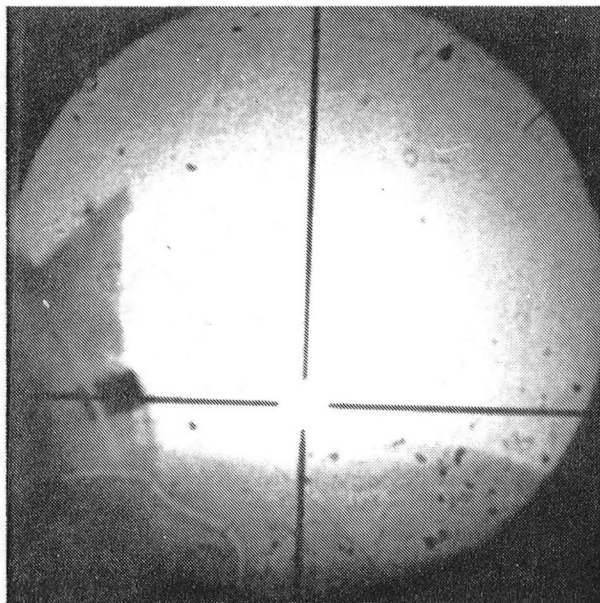


Figure 53.- Lightning attachment point scenario for strike 18, Flight 82-020.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 54. - Strike 18, Flight 82-020, aft camera.

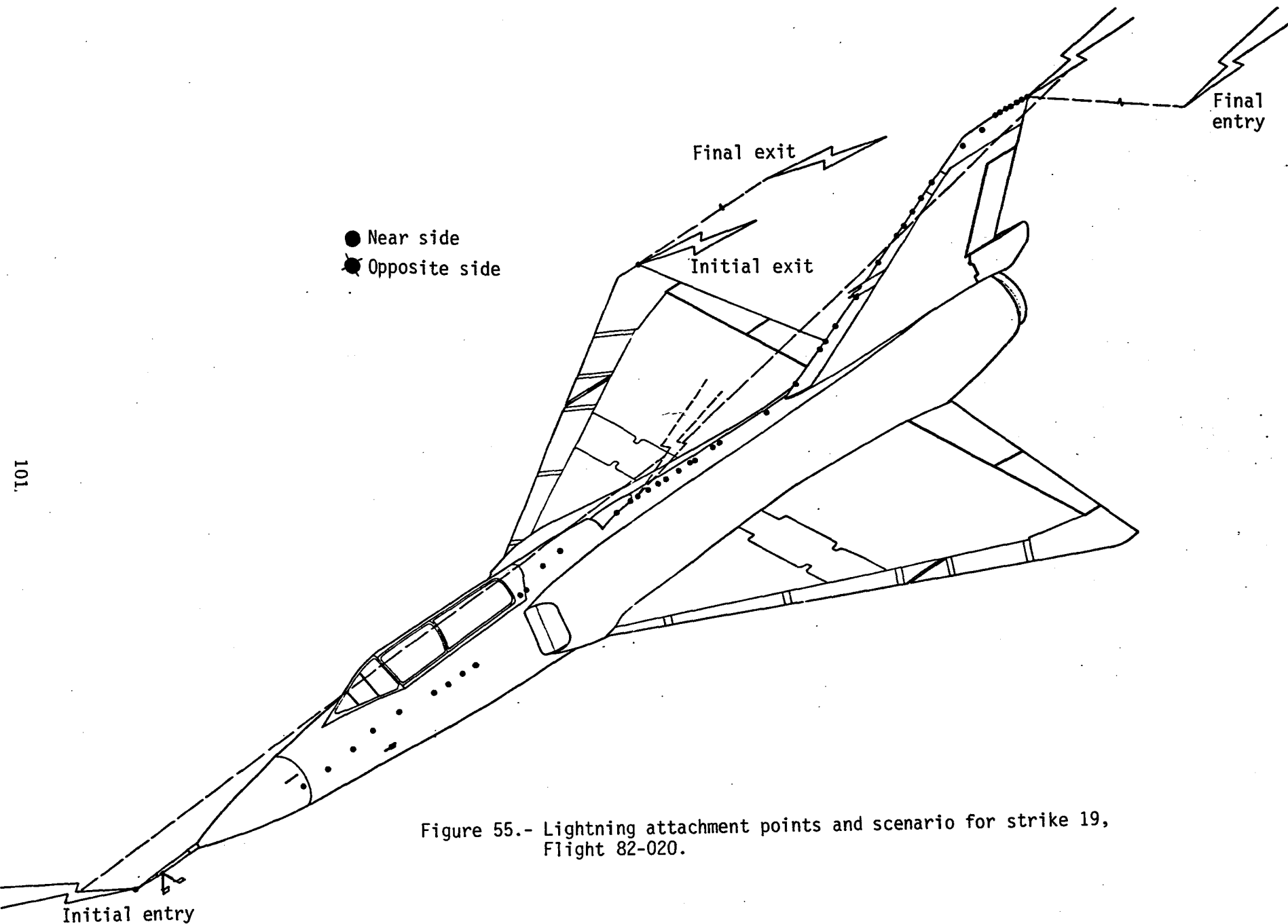


Figure 55.- Lightning attachment points and scenario for strike 19, Flight 82-020.

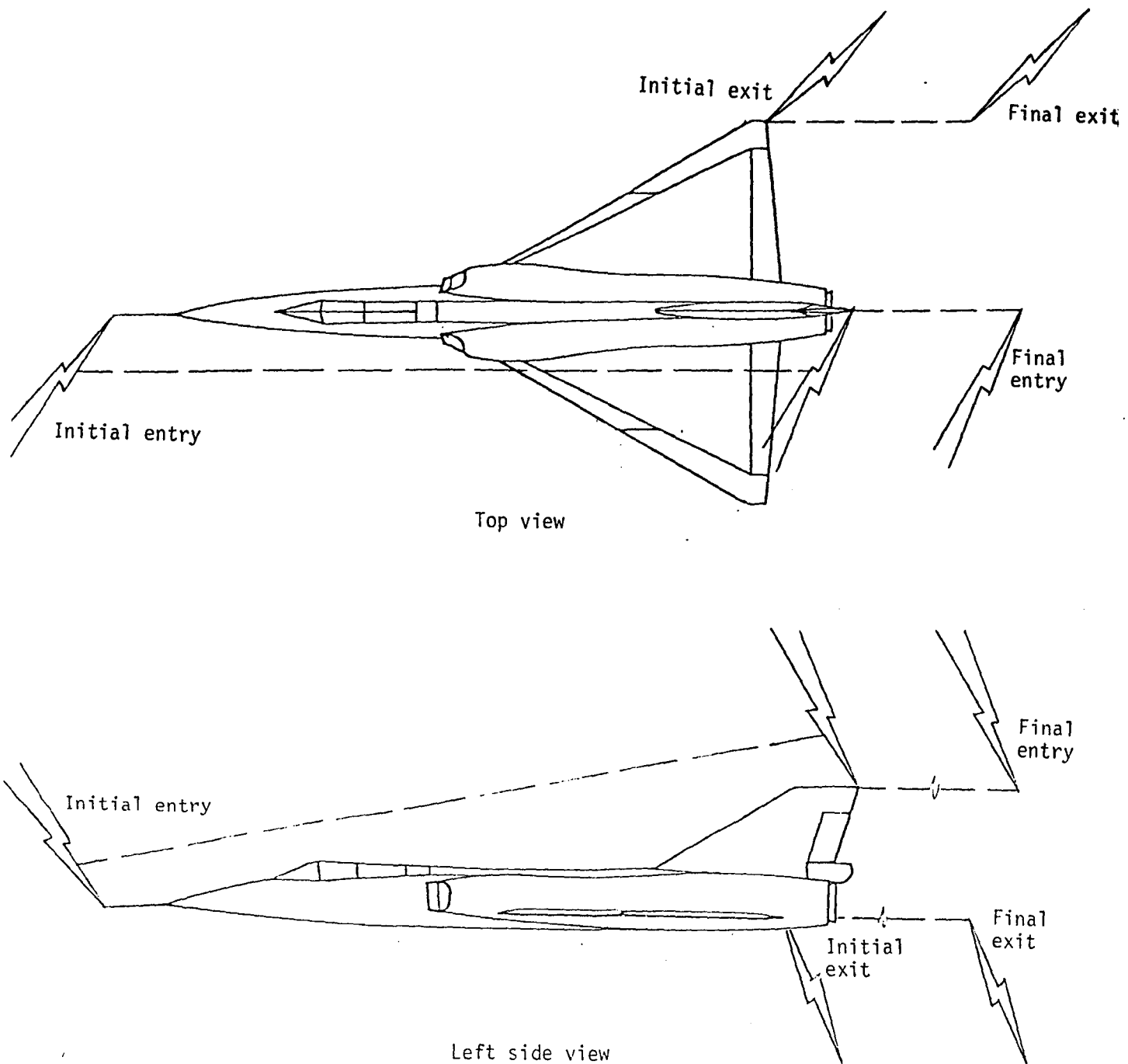


Figure 56.- Lightning attachment point scenario for strike 19, Flight 82-020.

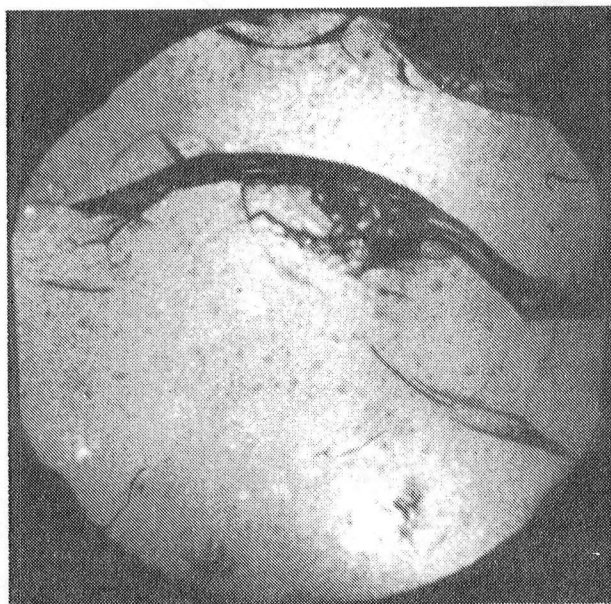
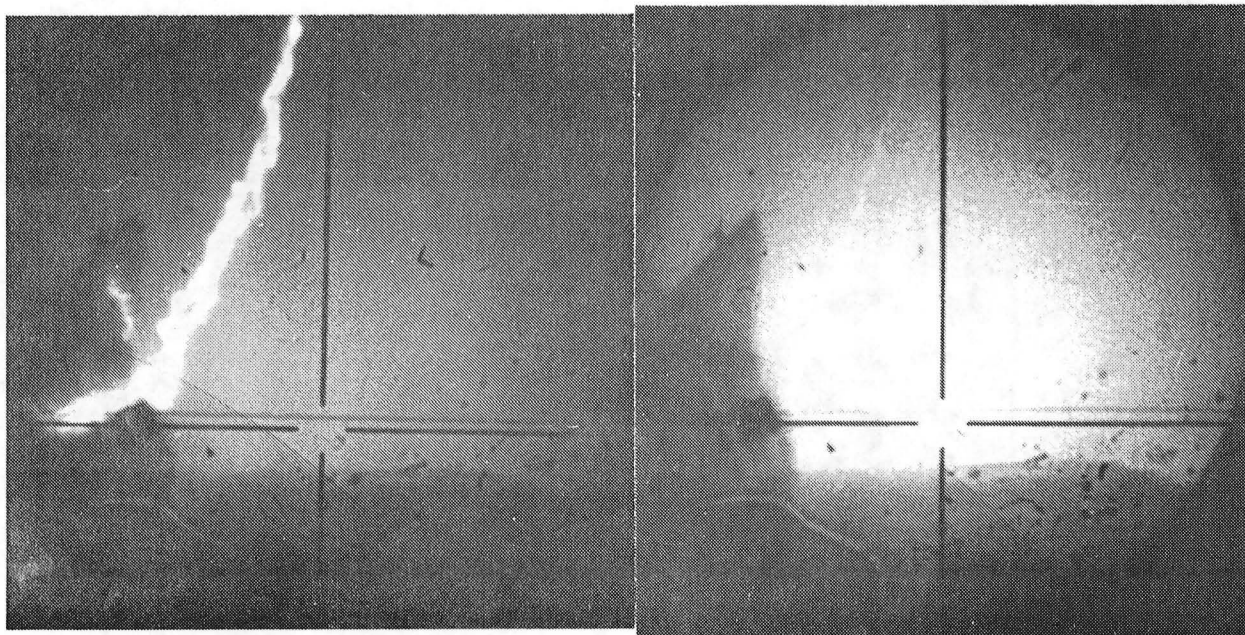


Figure 57. - Strike 20, Flight 82-023, forward camera.



(a) Frame 1 of 2.

(b) Frame 2 of 2.

Figure 58. - Strike 20, Flight 82-023, aft camera.

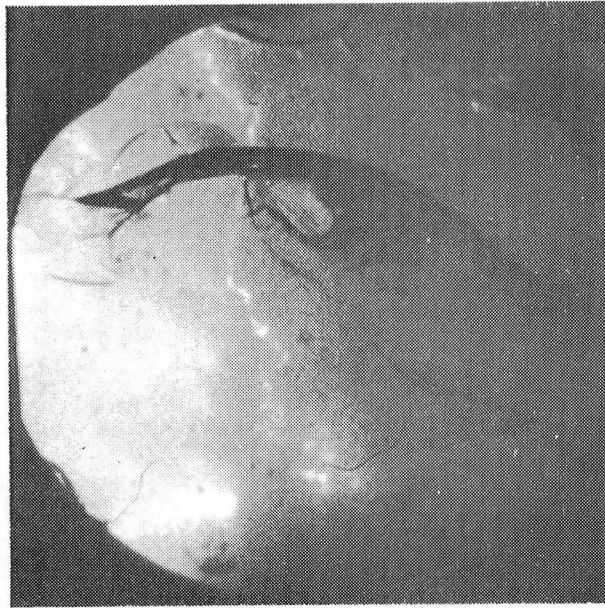
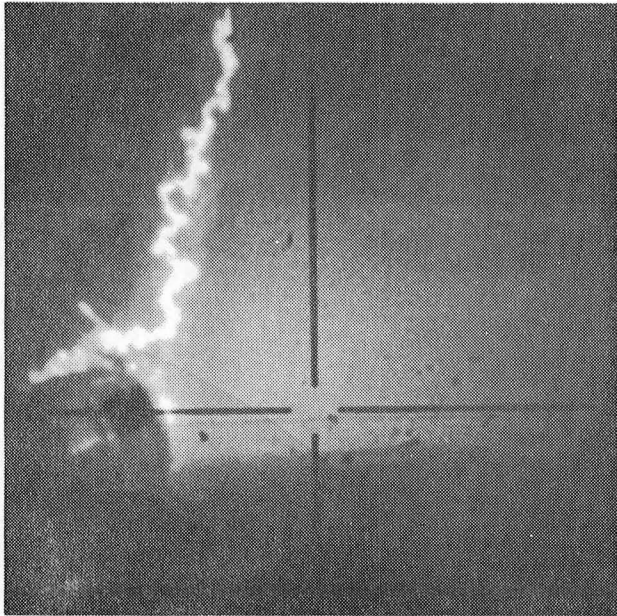
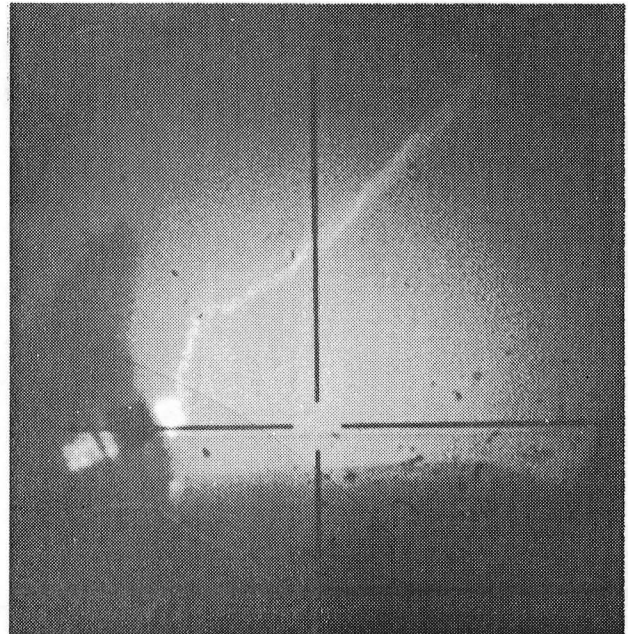


Figure 59. Strike 21, Flight 82-023, forward camera.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 60. - Strike 82-023, aft camera.

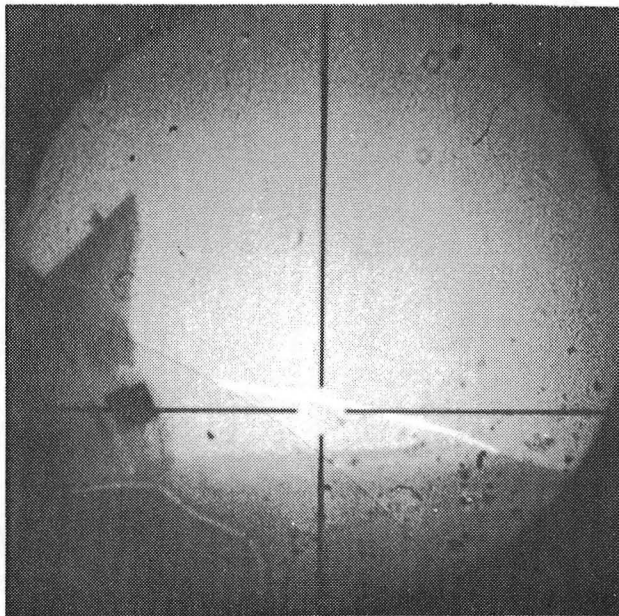
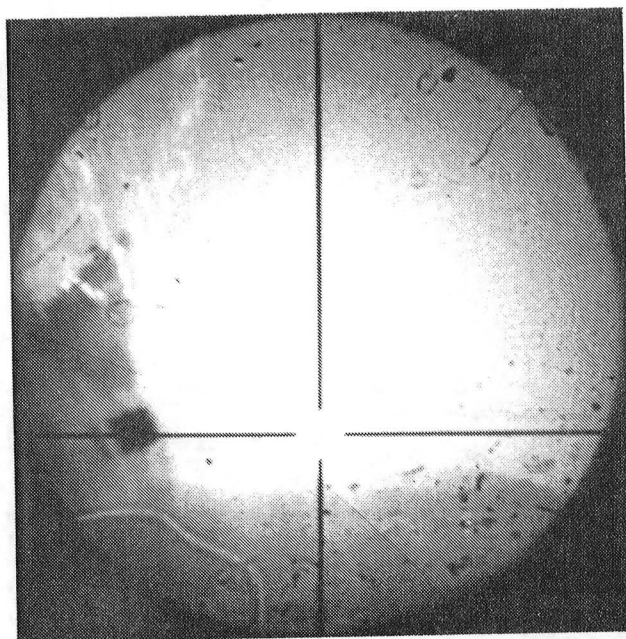


Figure 61. - Strike 22, Flight 82-023, aft camera.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 62. - Strike 23, Flight 82-023, aft camera.



Figure 63. - Strike 24, Flight 82-023, forward camera.

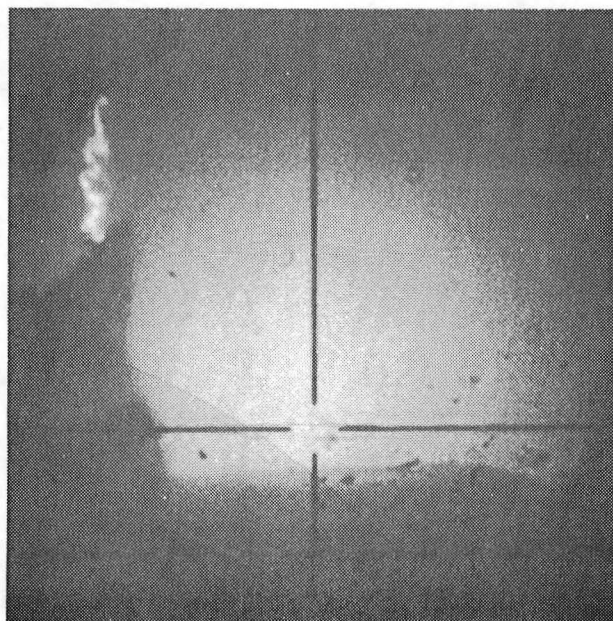
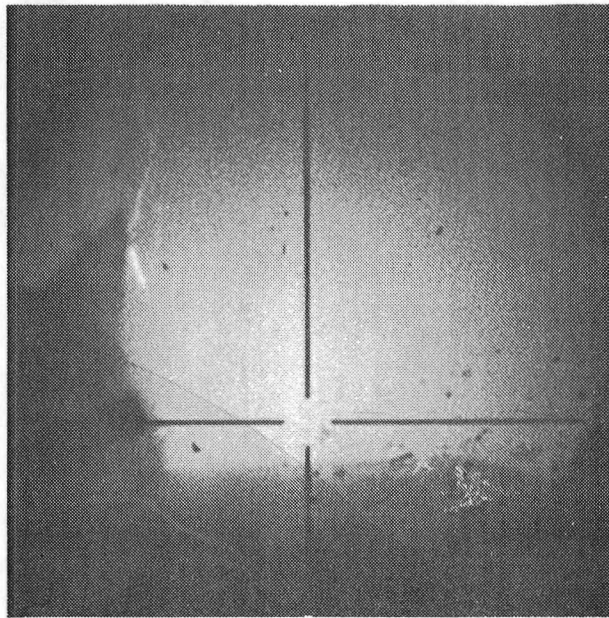
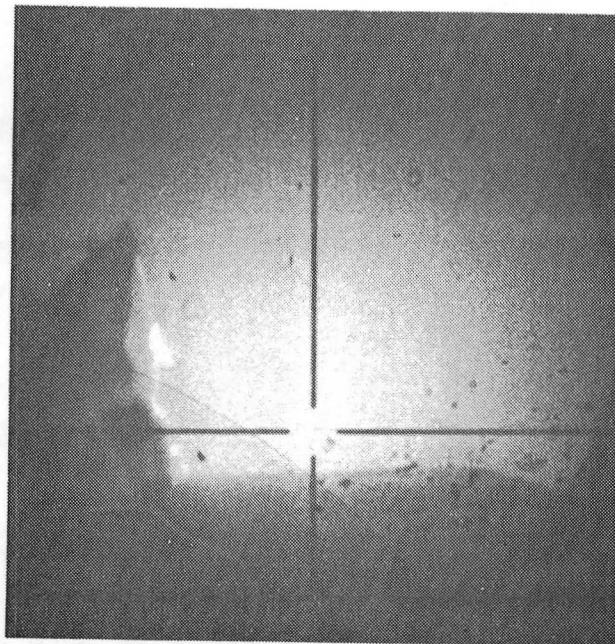


Figure 64. - Strike 24, Flight 82-023, aft camera.

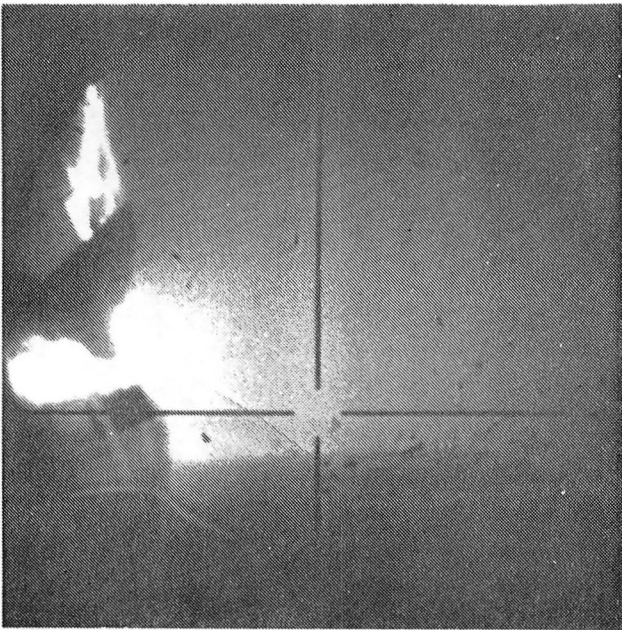


(a) Frame 1 of 2.

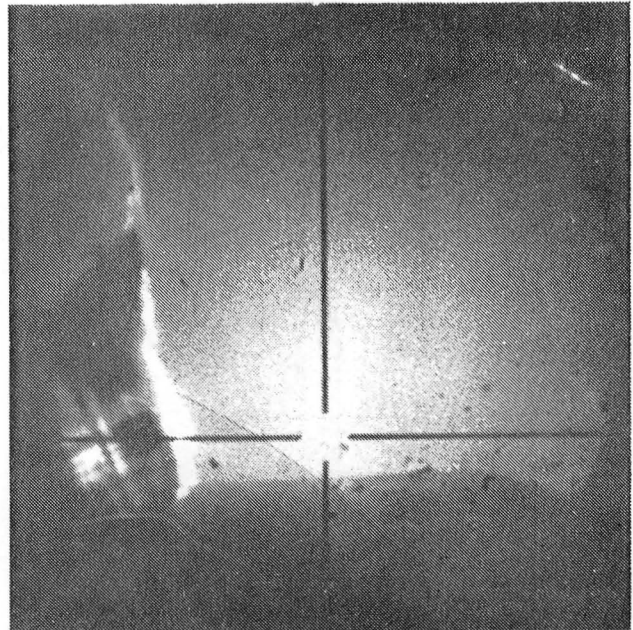


(b) Frame 2 of 2.

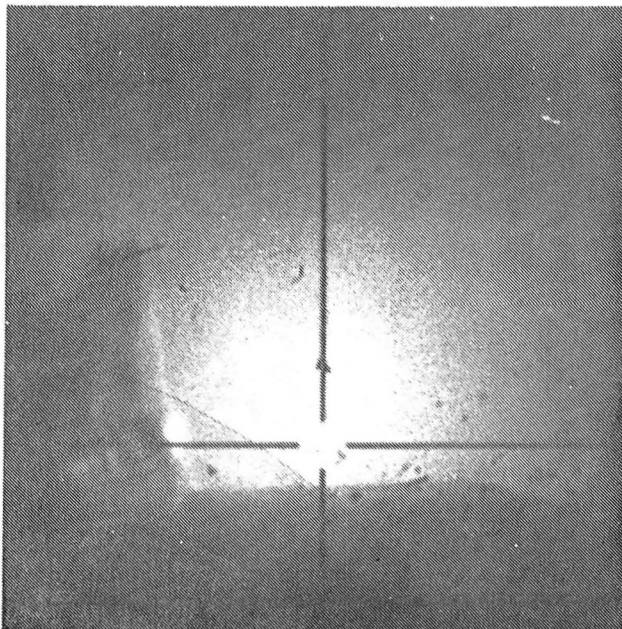
Figure 65. - Strike 25, Flight 82-023, aft camera.



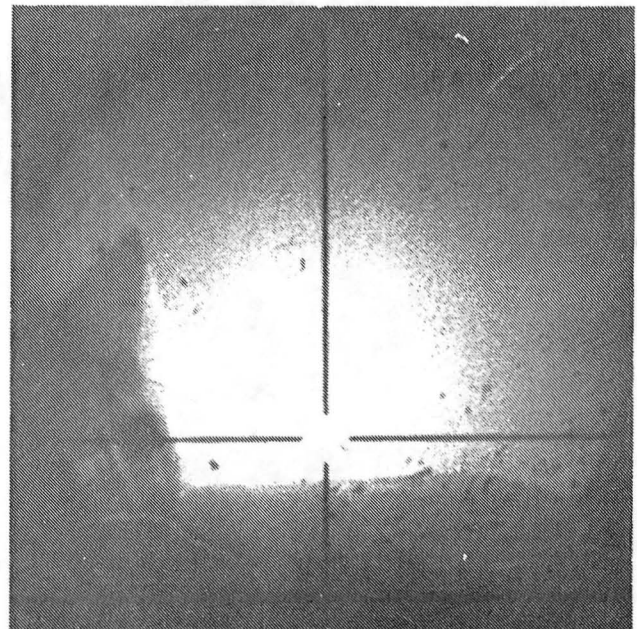
(a) Frame 1 of 5.



(b) Frame 2 of 5.

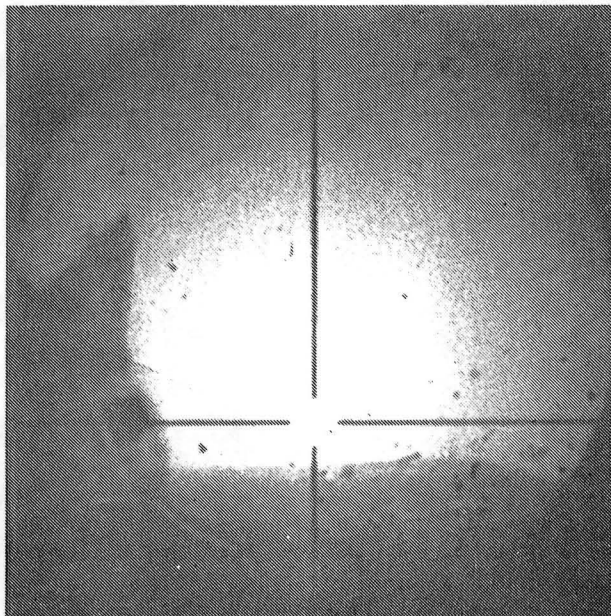


(c) Frame 3 of 5.



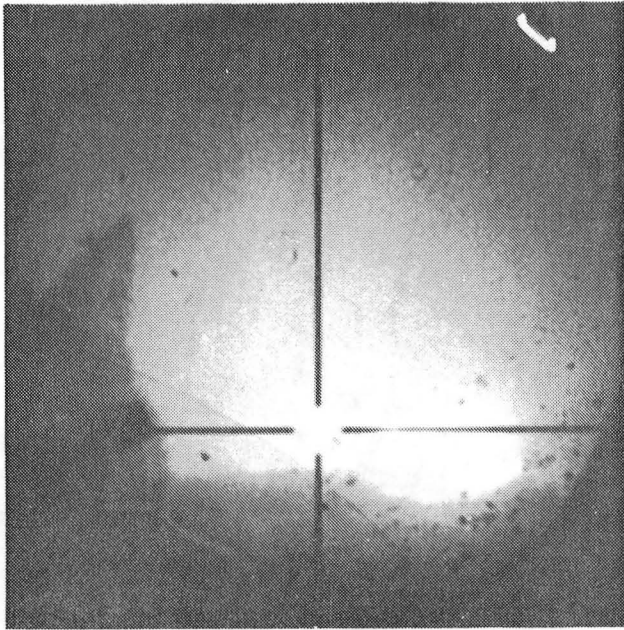
(d) Frame 4 of 5.

Figure 66. - Strike 26, Flight 82-023, aft camera.

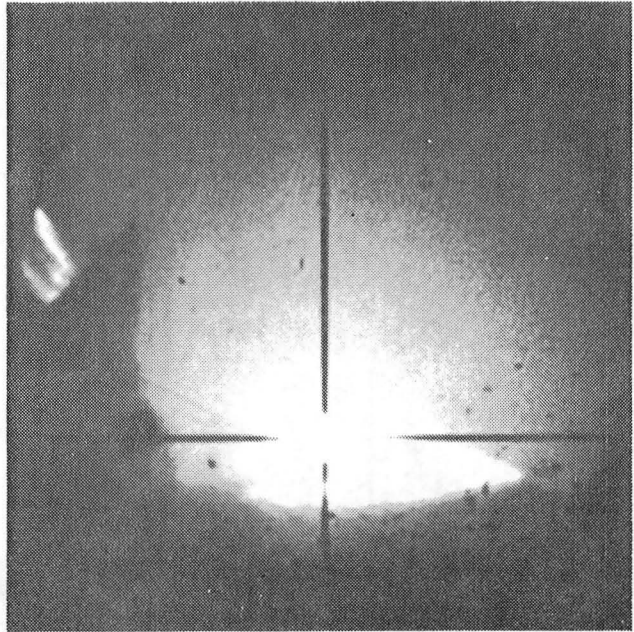


(e) Frame 5 of 5.

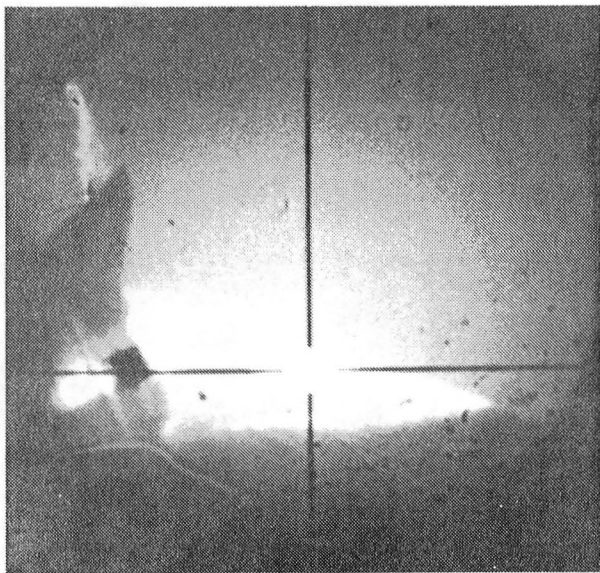
Figure 66. - Concluded.



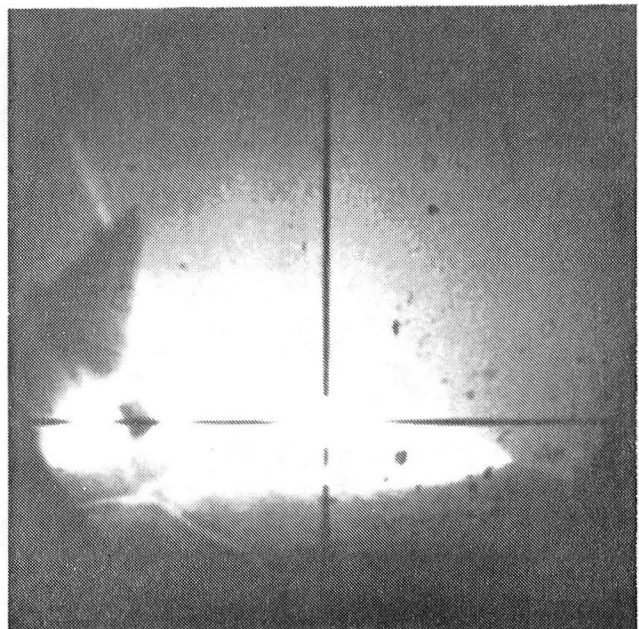
(a) Frame 1 of 10.



(b) Frame 2 of 10.



(c) Frame 3 of 10.

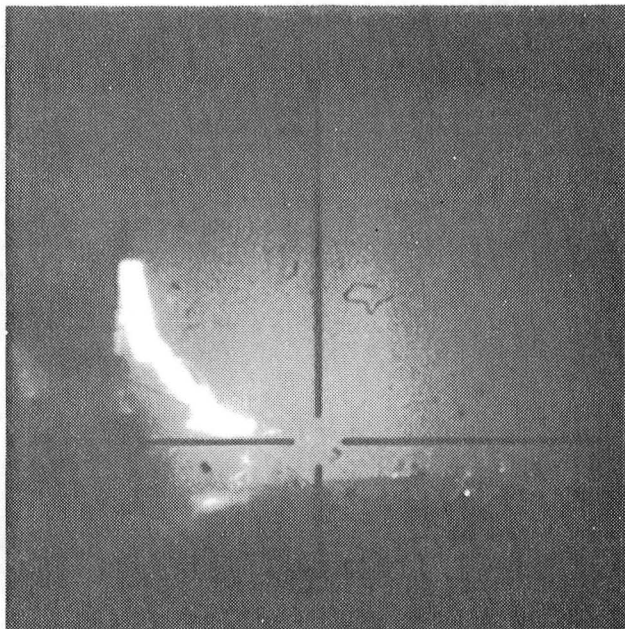


(d) Frame 4 of 10.

Figure 67. - Strike 27, Flight 82-023, aft camera.



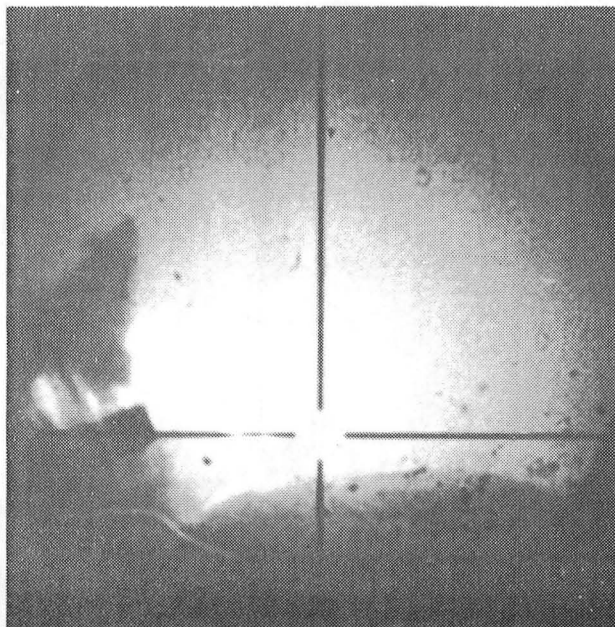
(e) Frame 5 of 10.



(f) Frame 6 of 10.



(g) Frame 7 of 10.

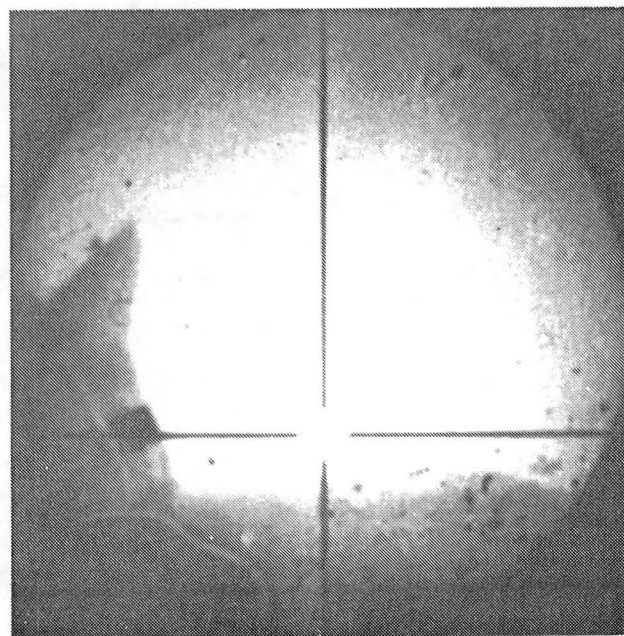


(h) Frame 8 of 10.

Figure 67. - Continued.



(i) Frame 9 of 10.



(j) Frame 10 of 10.

Figure 67. - Concluded.

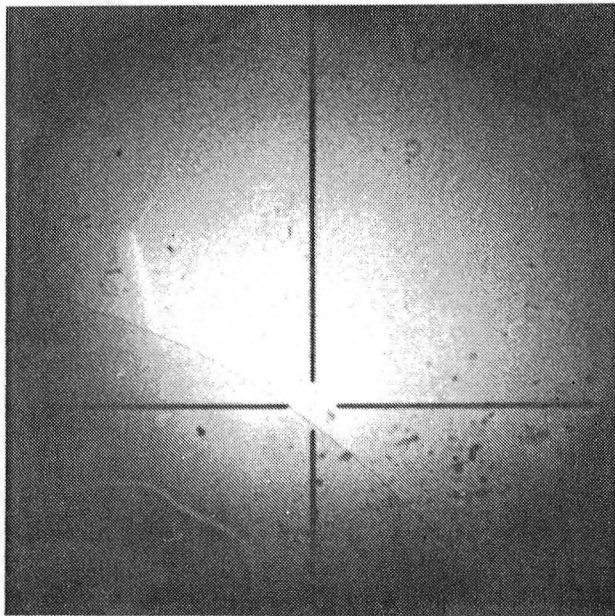
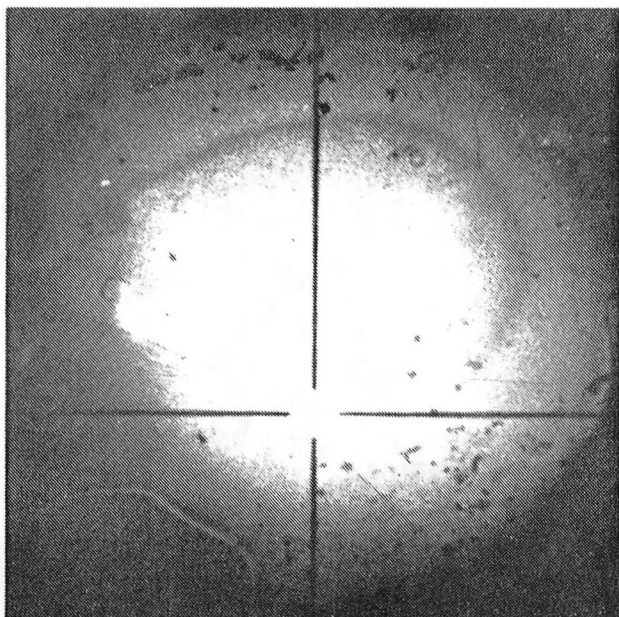
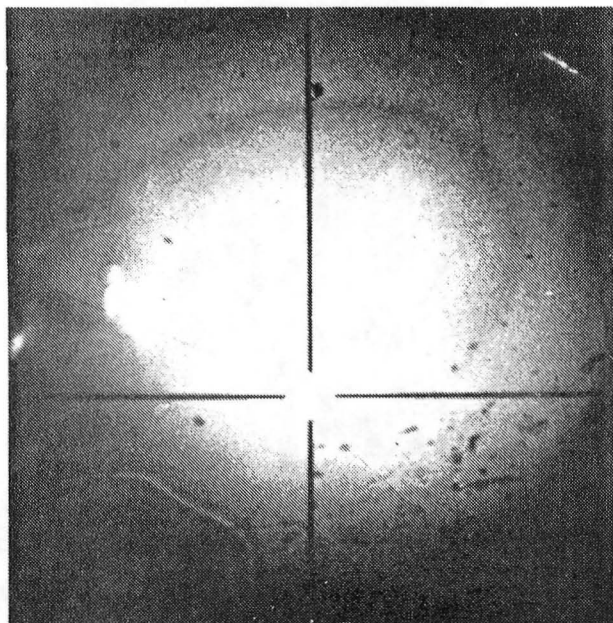


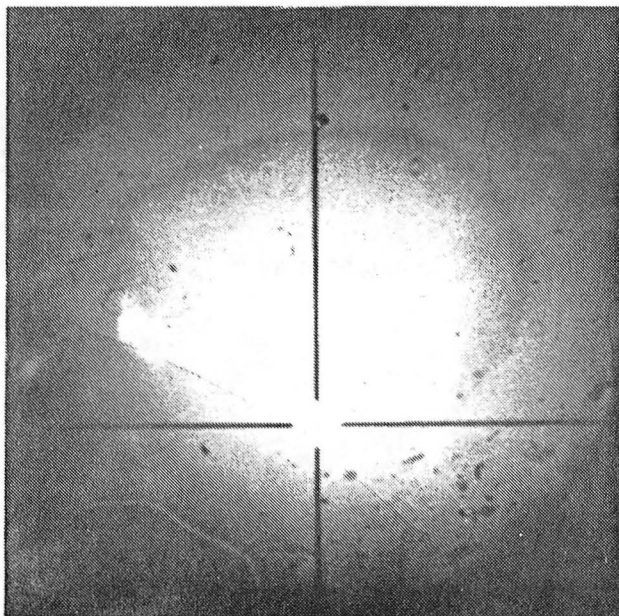
Figure 68. - Strike 31, Flight 82-024, aft camera.



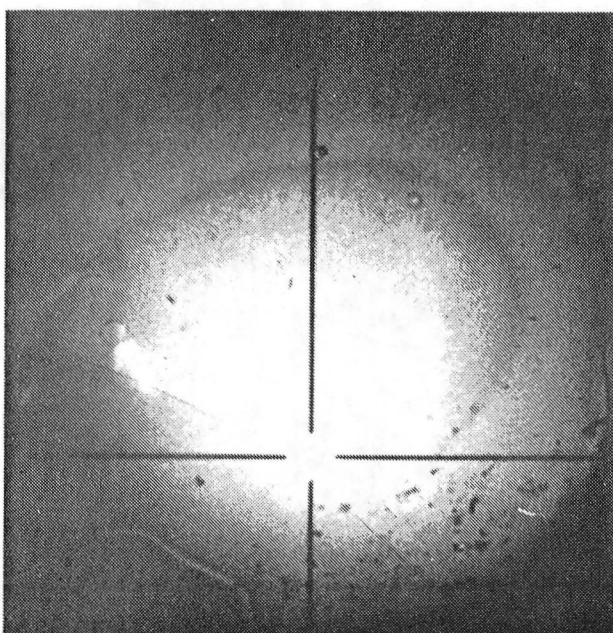
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.



(d) Frame 4 of 4.

Figure 69. - Strike 35, Flight 82-024, aft camera.

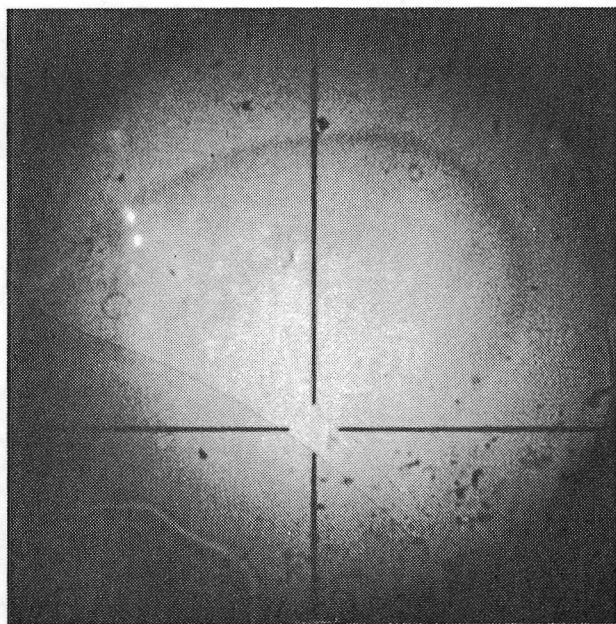


Figure 70. - Strike 36, Flight 82-024, aft camera.

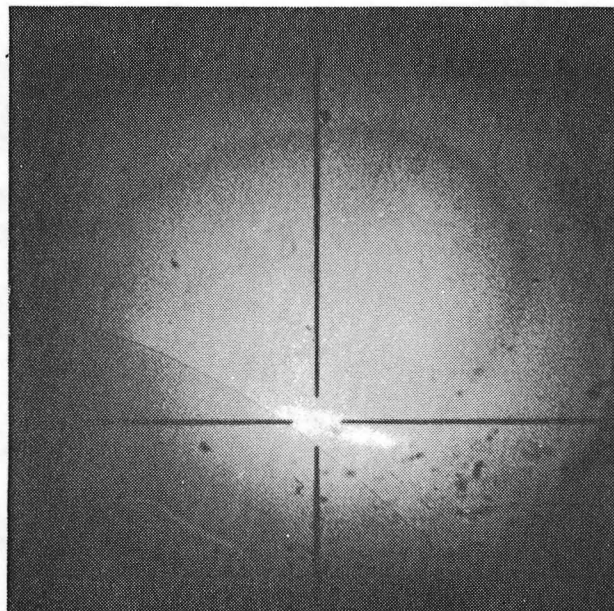


Figure 71. - Strike 37, Flight 82-024, aft camera.

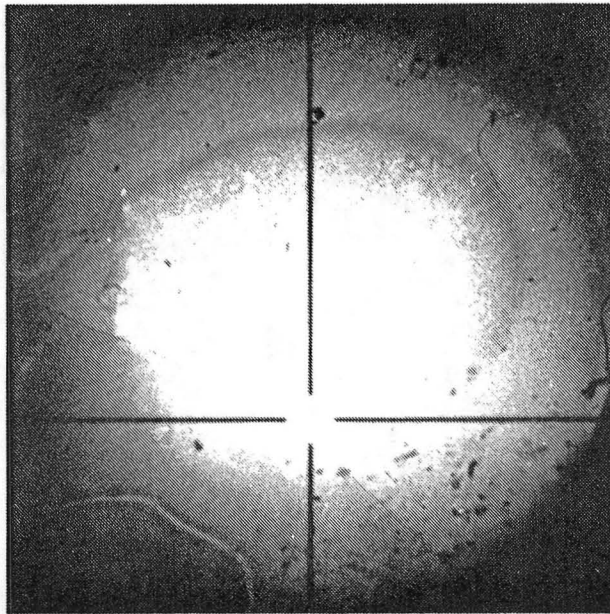
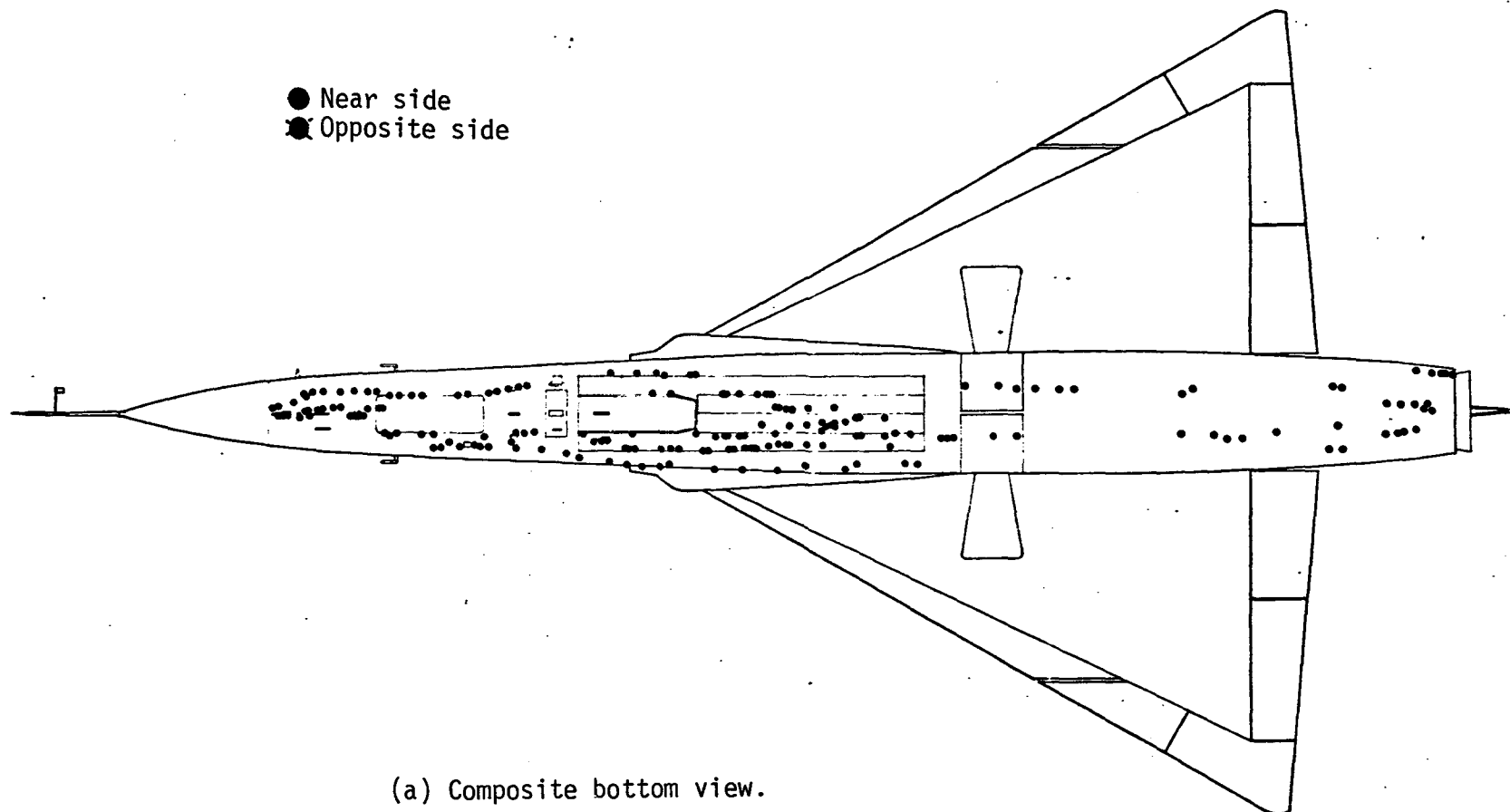
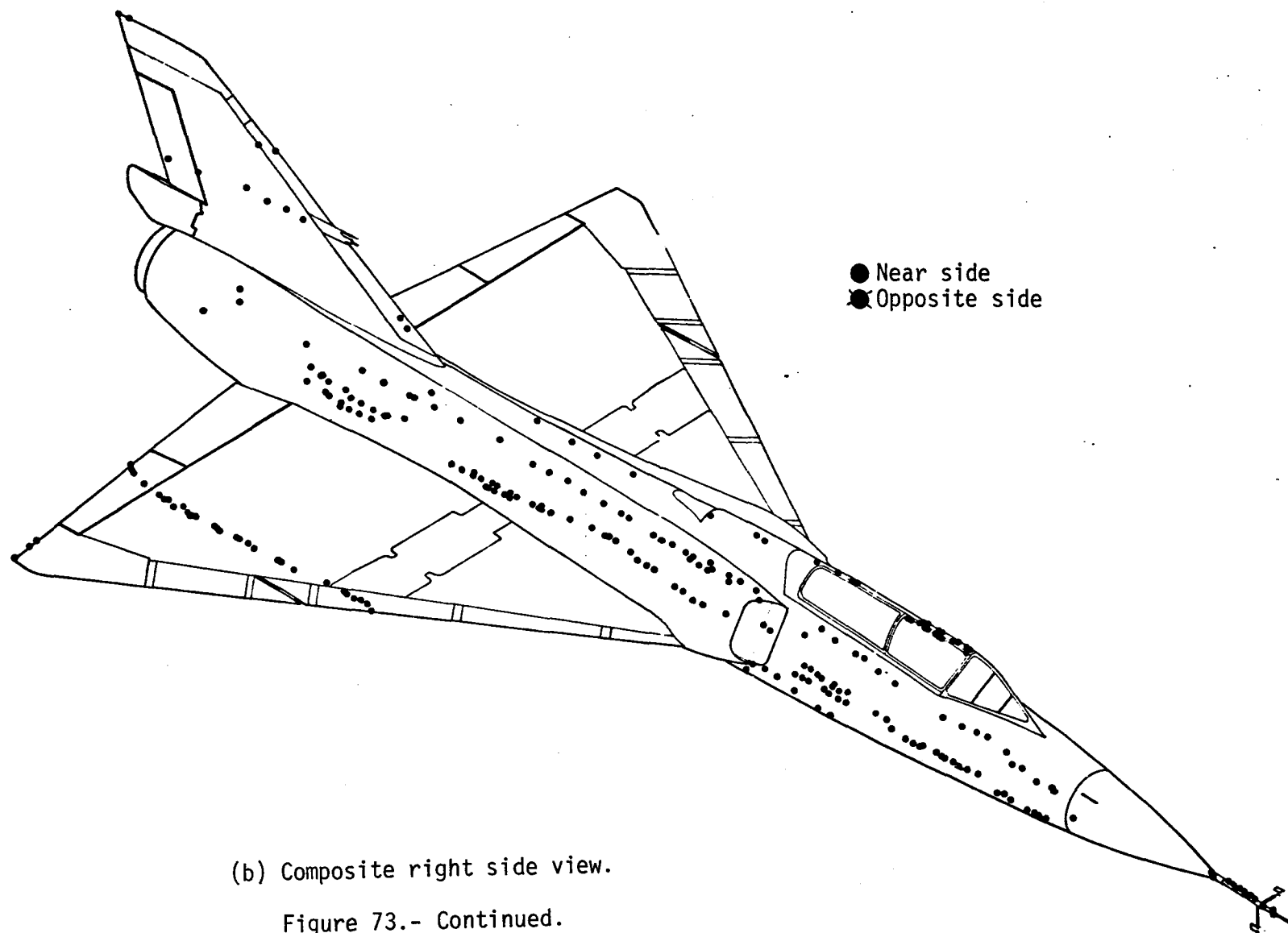


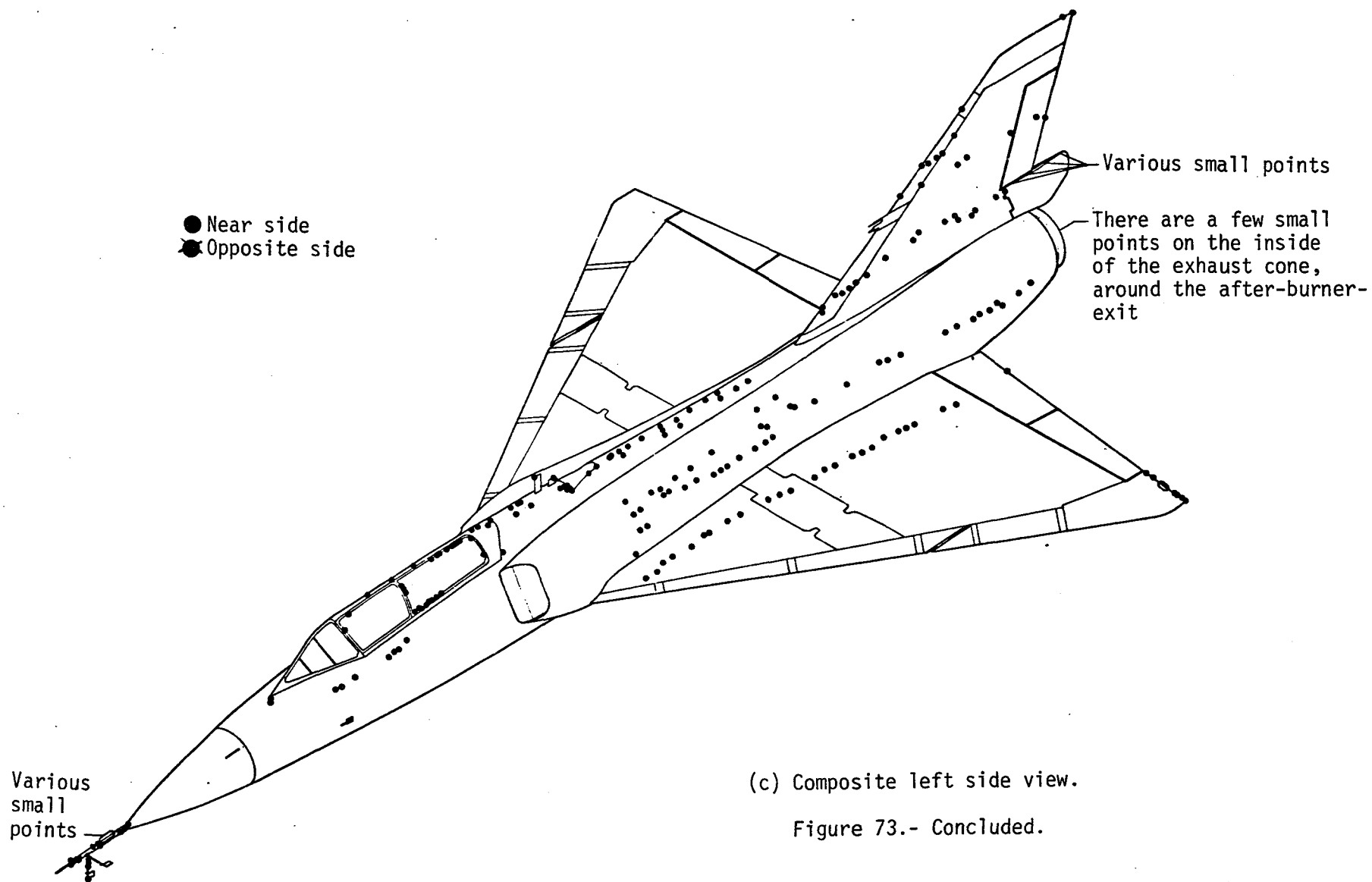
Figure 72. - Strike 38, Flight 82-024, aft camera.

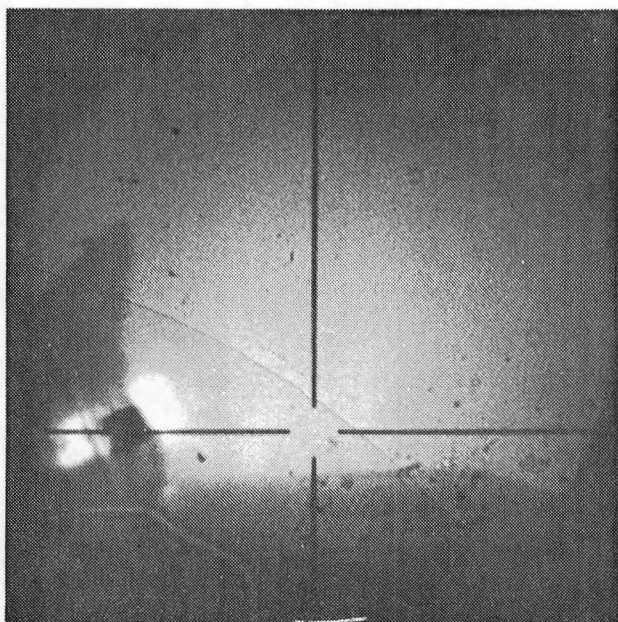


(a) Composite bottom view.

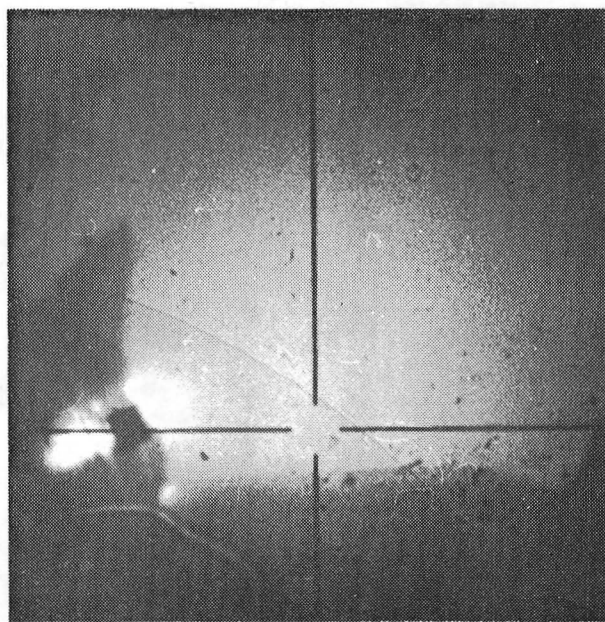
Figure 73.- Lightning attachment points for strikes 42-55,
Flights 82-026-028.



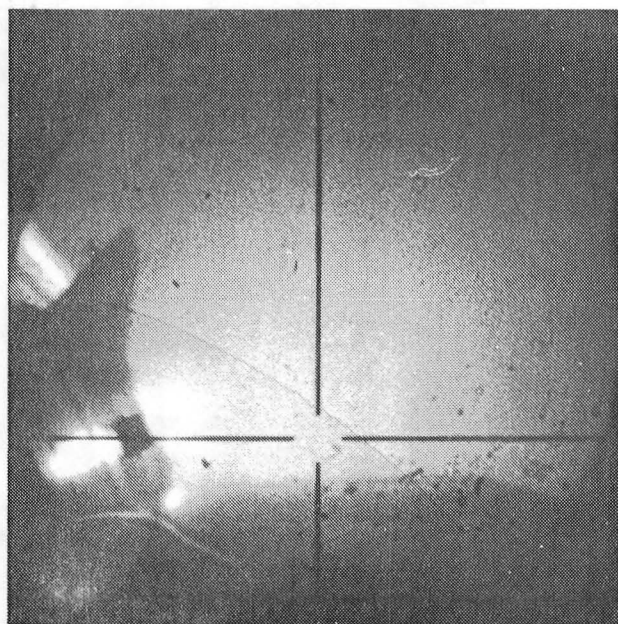




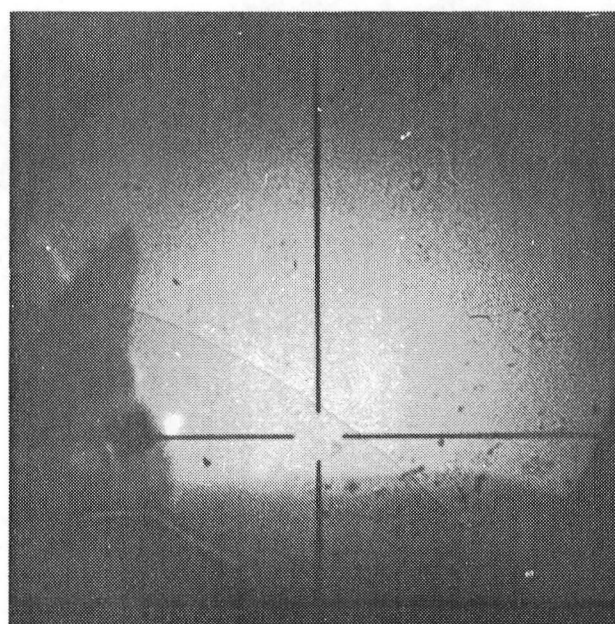
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.



(d) Frame 4 of 4.

Figure 74. - Strike 45, Flight 82-027, aft camera.

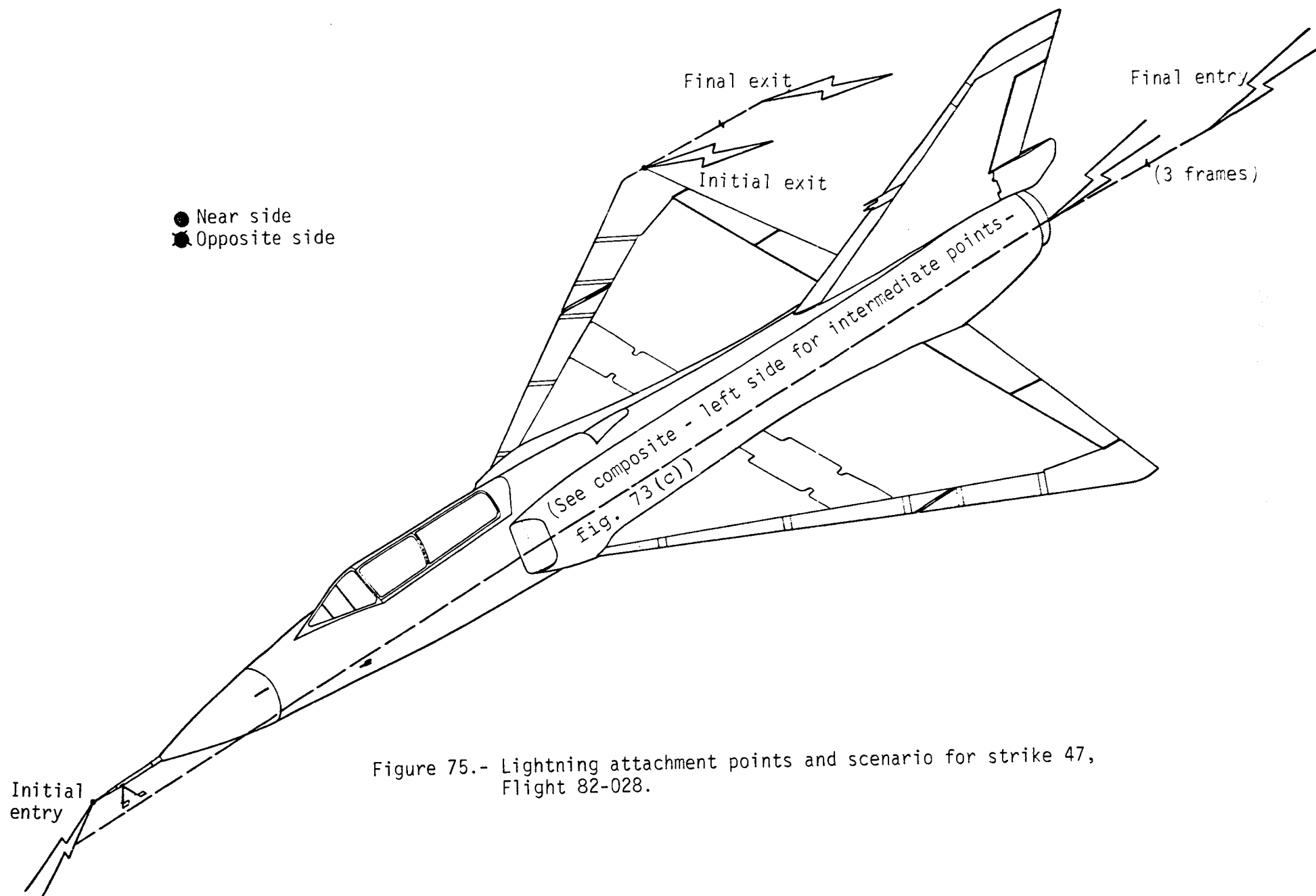
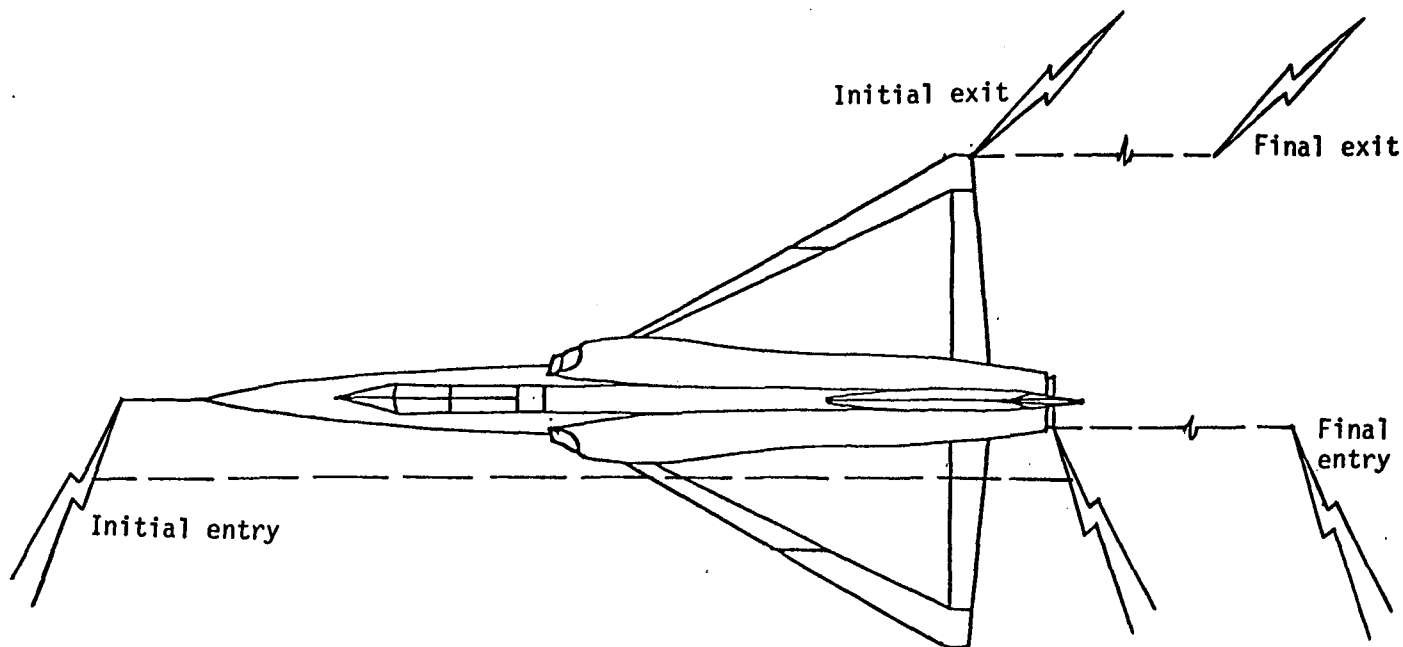
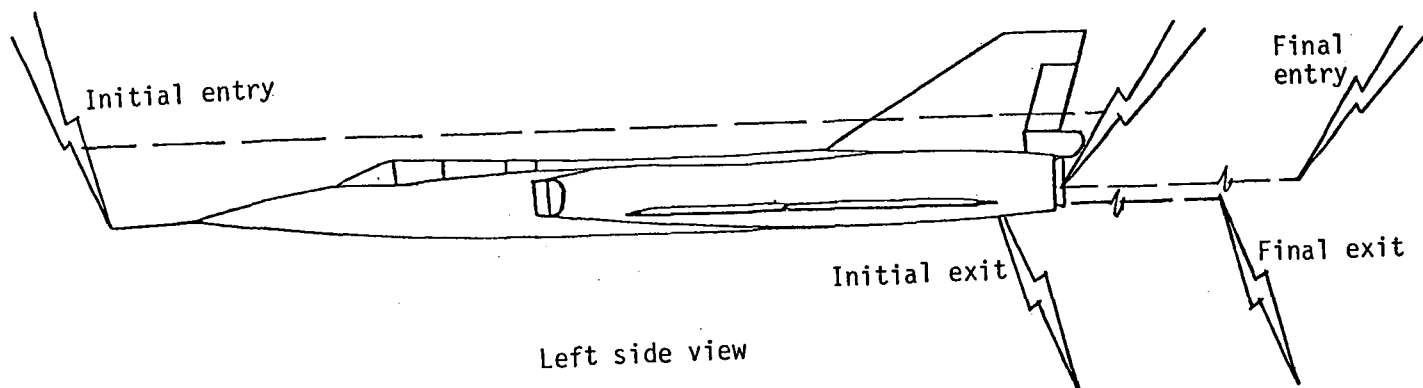


Figure 75.- Lightning attachment points and scenario for strike 47,
Flight 82-028.

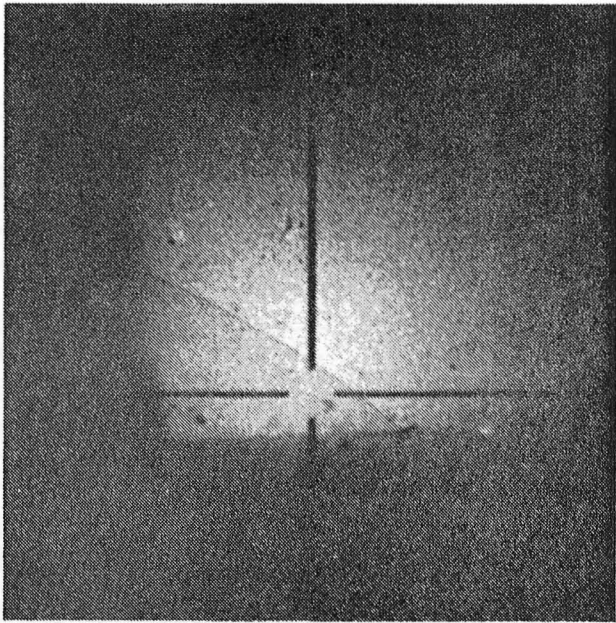


Top view

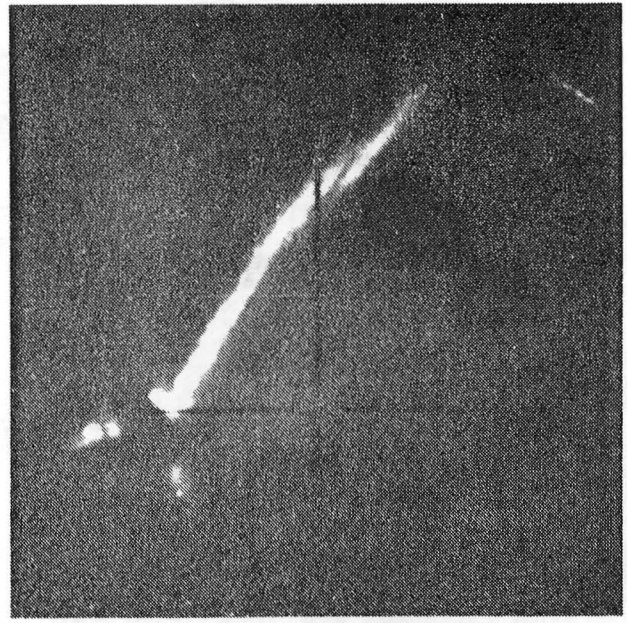


Left side view

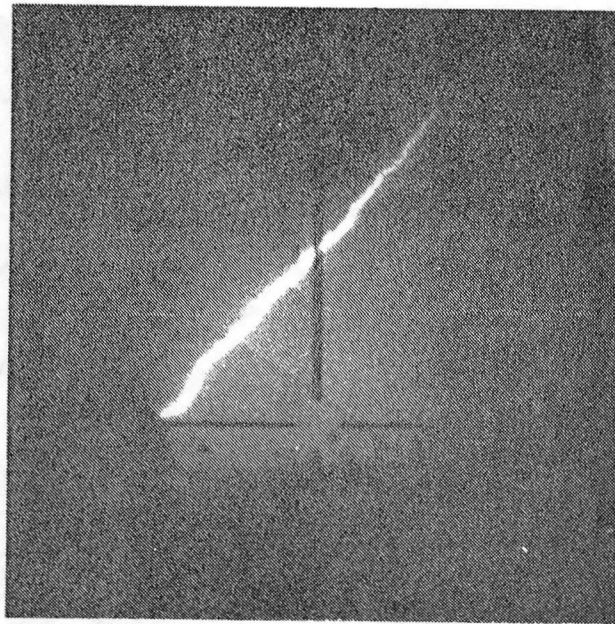
Figure 76.- Lightning attachment point scenario for strike 47, Flight 82-028.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 77. - Strike 47, Flight 82-028, aft camera.

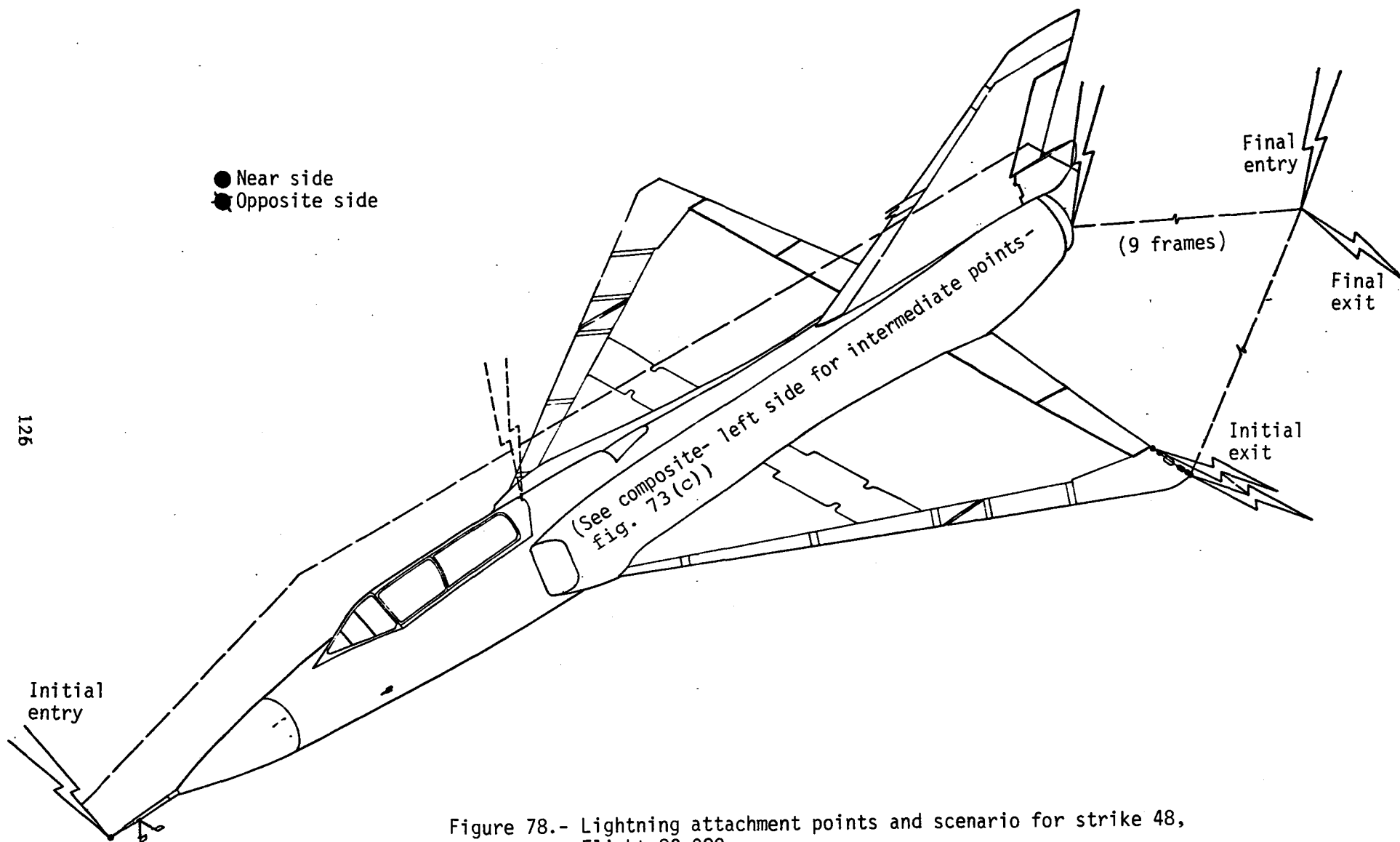


Figure 78.- Lightning attachment points and scenario for strike 48,
Flight 82-028.

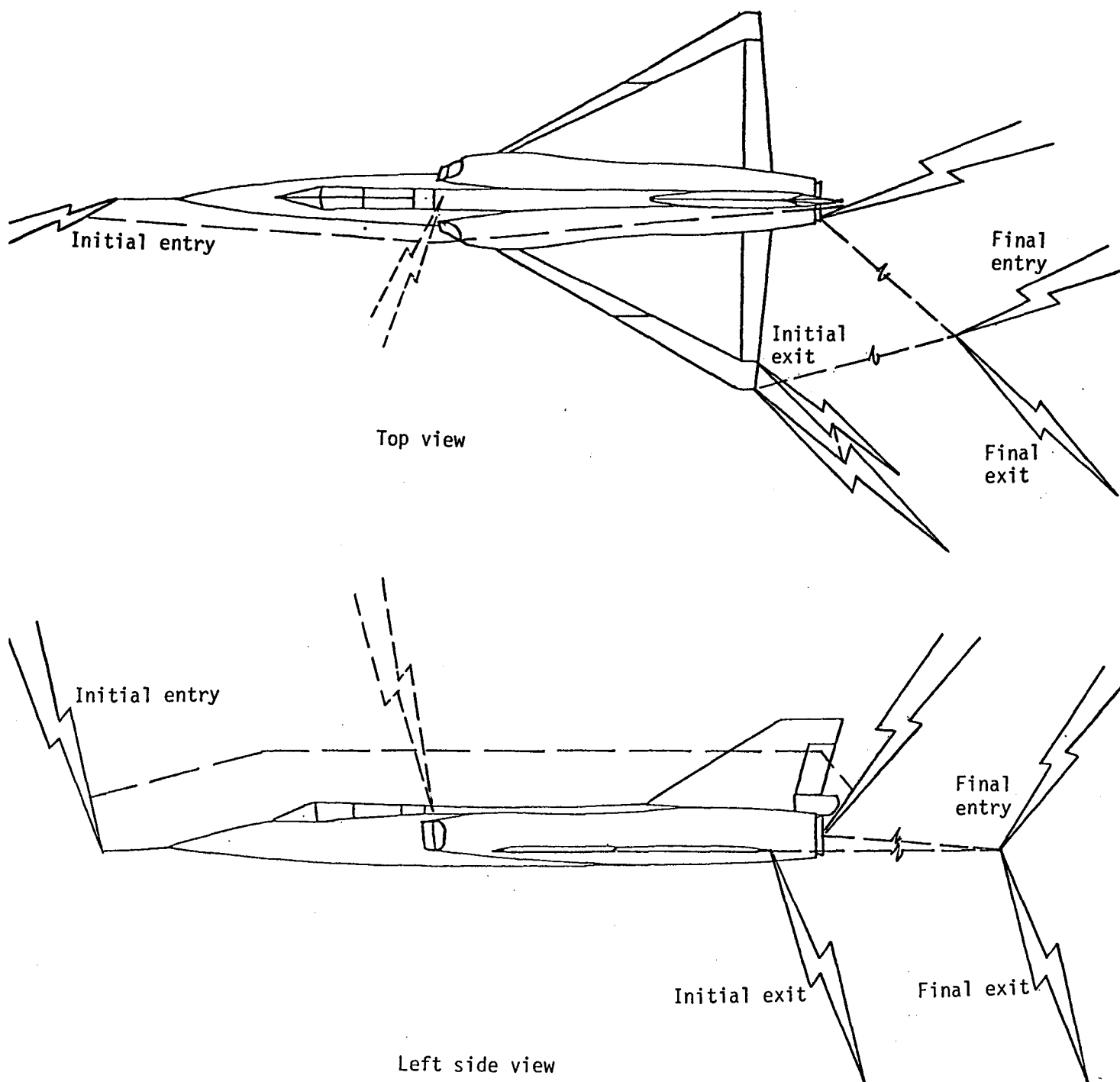
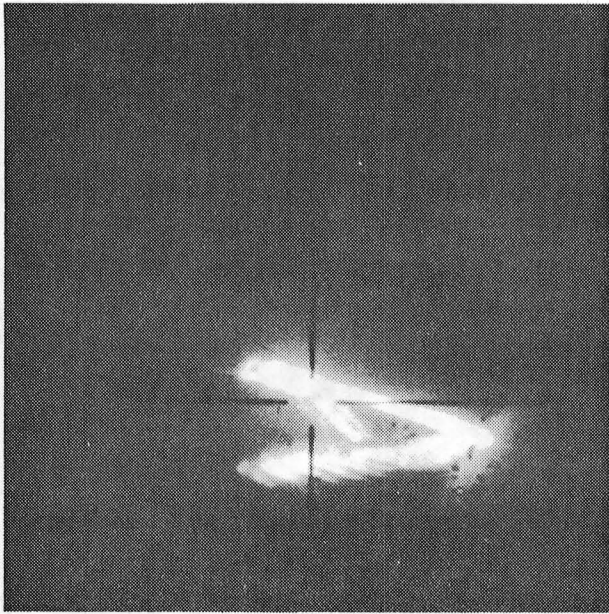
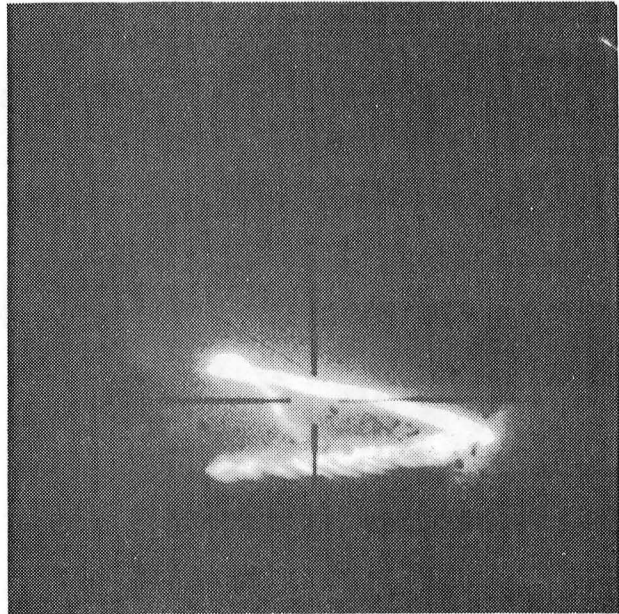


Figure 79.- Lightning attachment point scenario for strike 48, Flight 82-028.



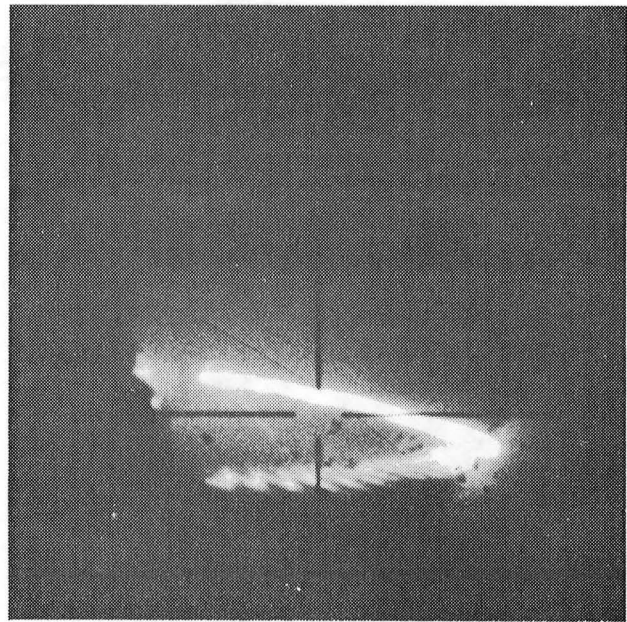
(a) Frame 1 of 9.



(b) Frame 2 of 9.

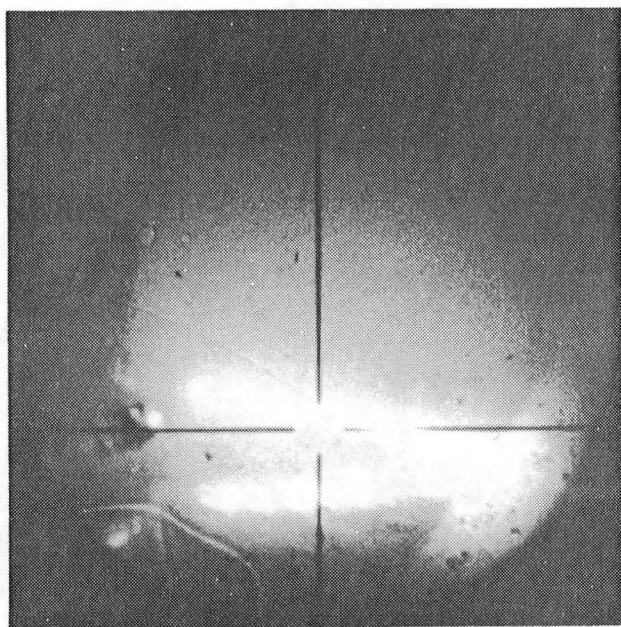


(c) Frame 3 of 9.

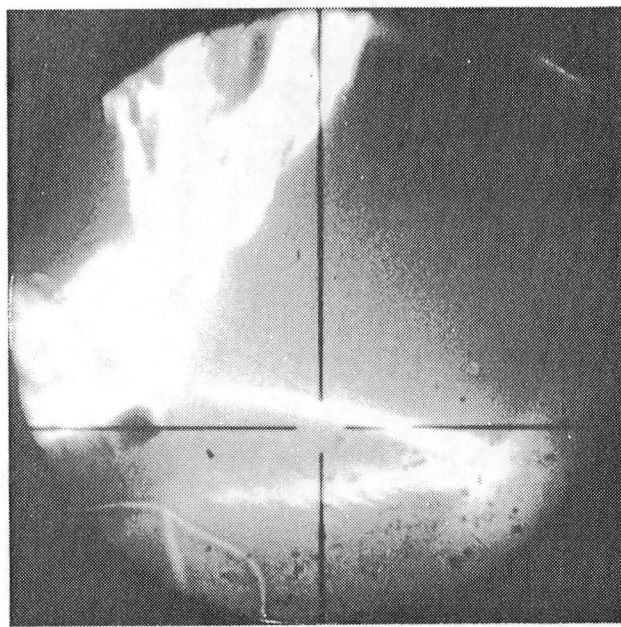


(d) Frame 4 of 9.

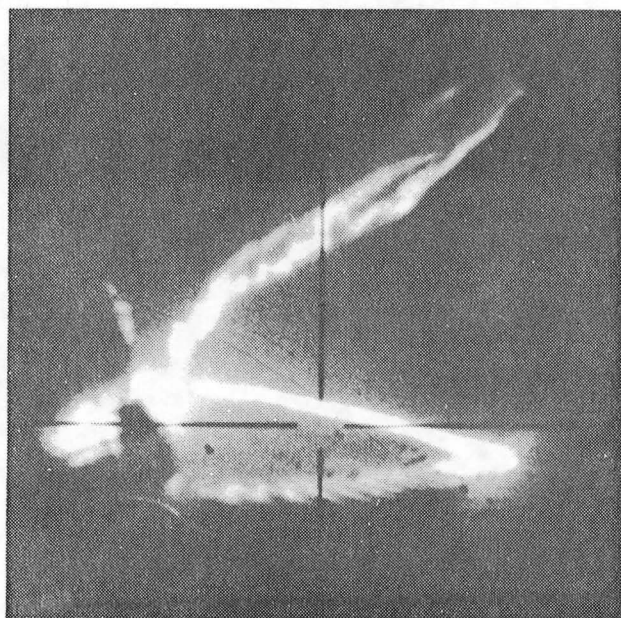
Figure 80. - Strike 48, Flight 82-028, aft camera.



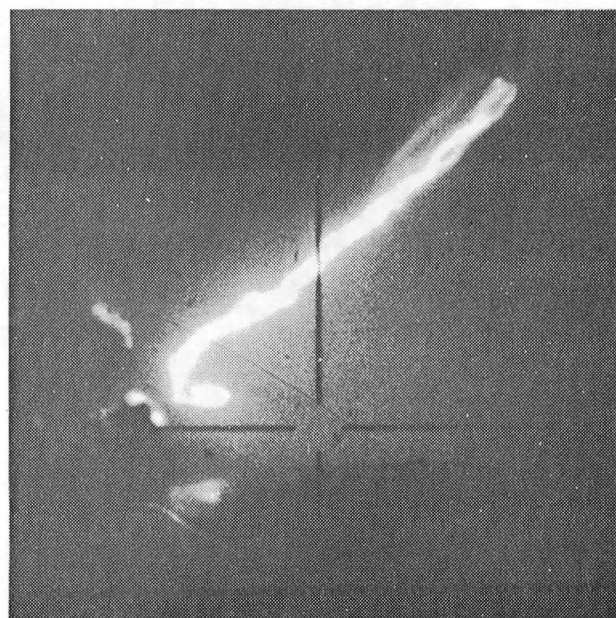
(e) Frame 5 of 9.



(f) Frame 6 of 9.

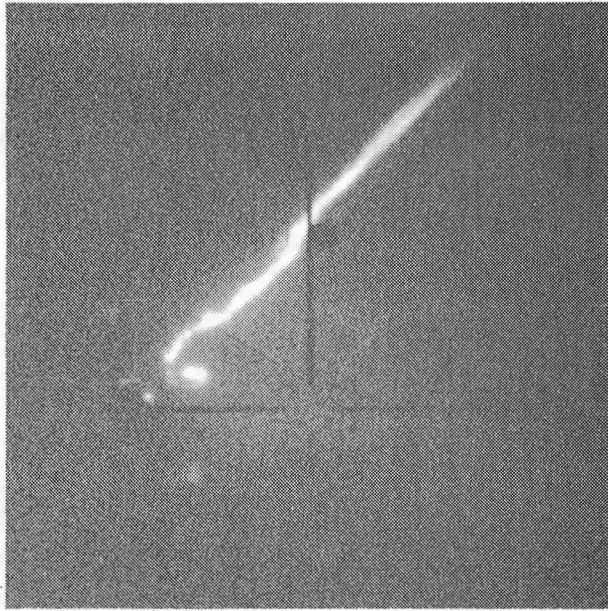


(g) Frame 7 of 9.



(h) Frame 8 of 9.

Figure 80. - Continued.



(i) Frame 9 of 9.

Figure 80. - Concluded.

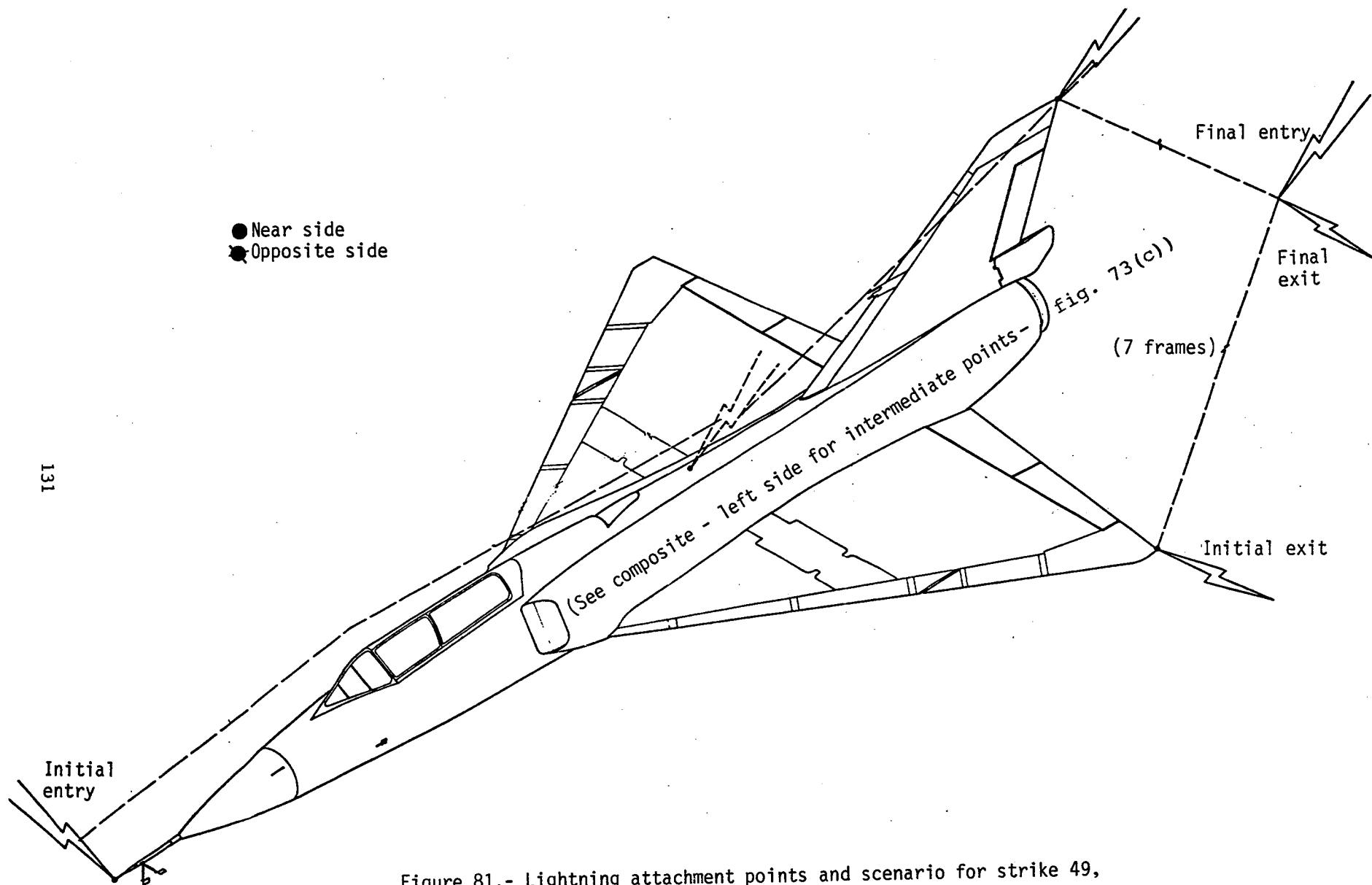


Figure 81.- Lightning attachment points and scenario for strike 49, Flight 82-028.

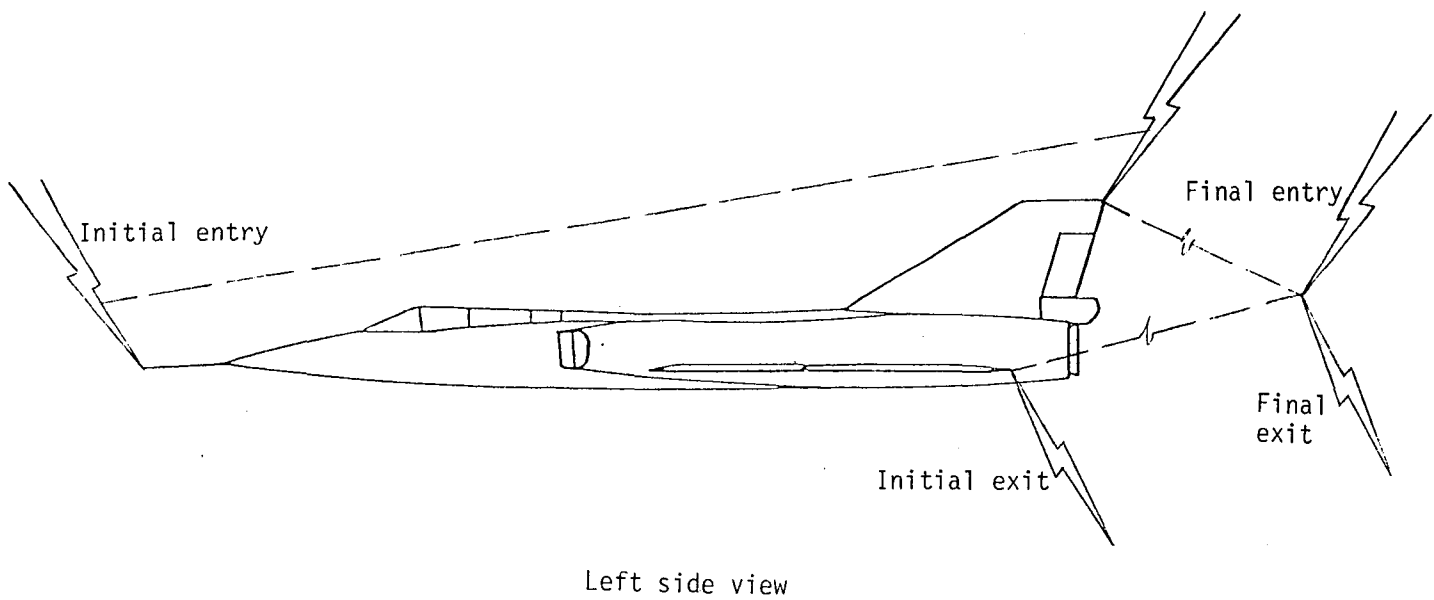
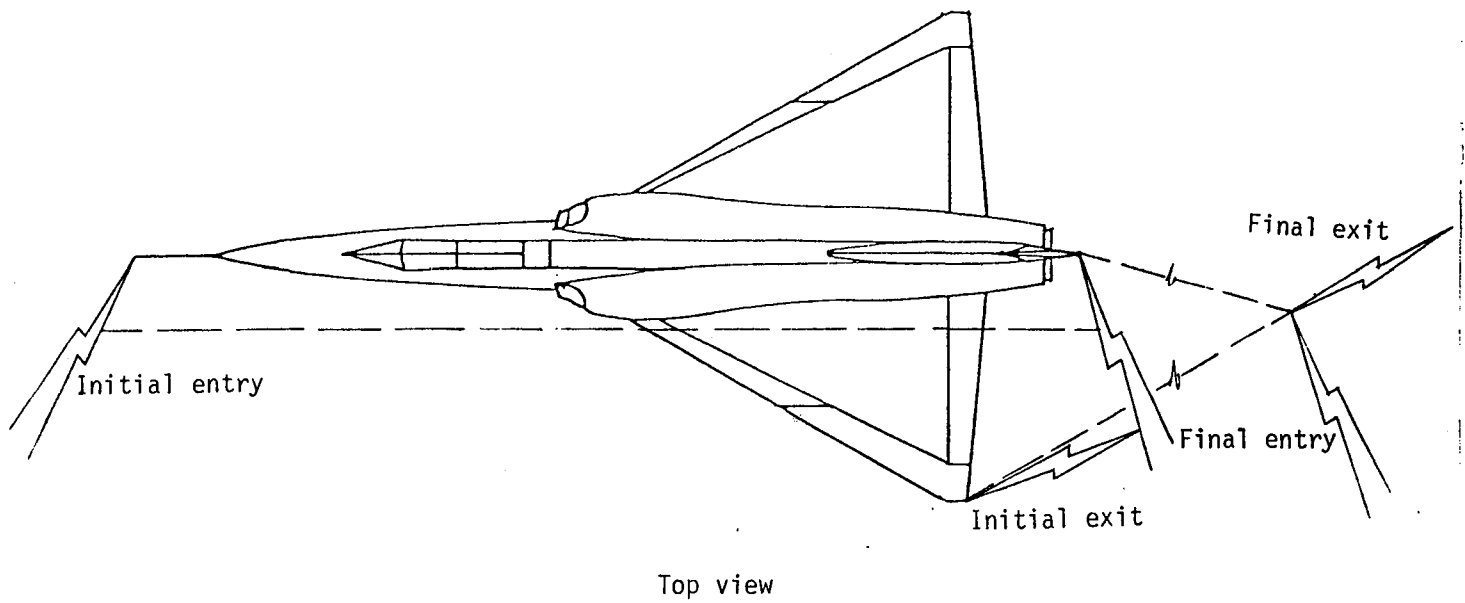
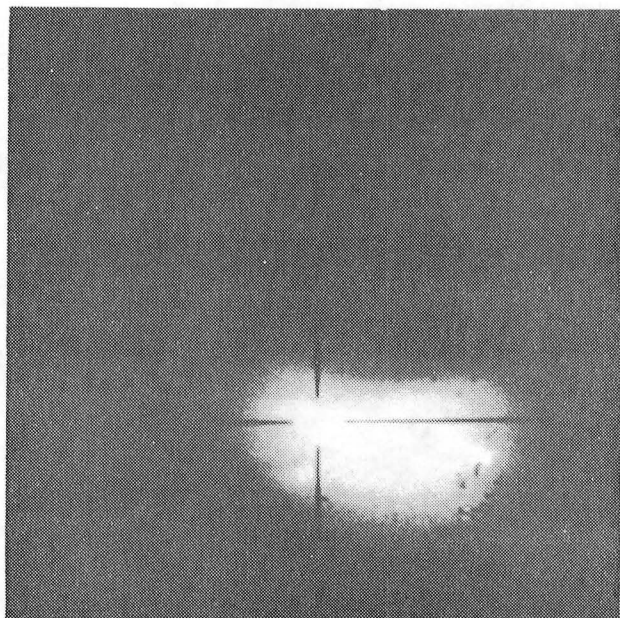
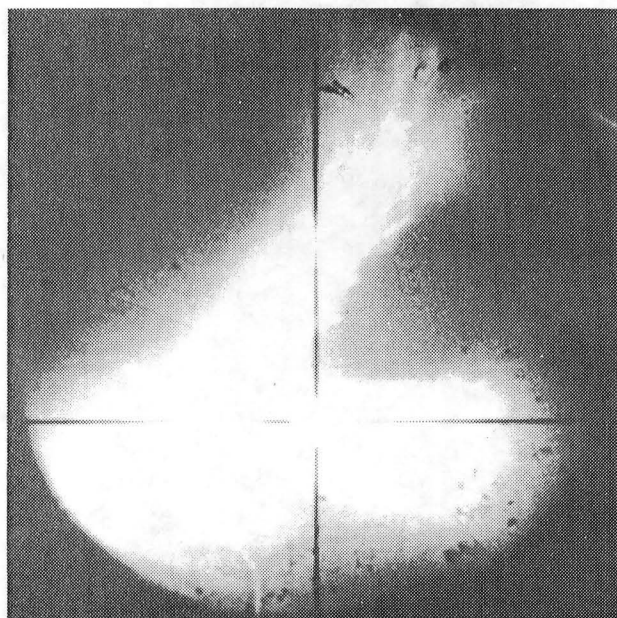


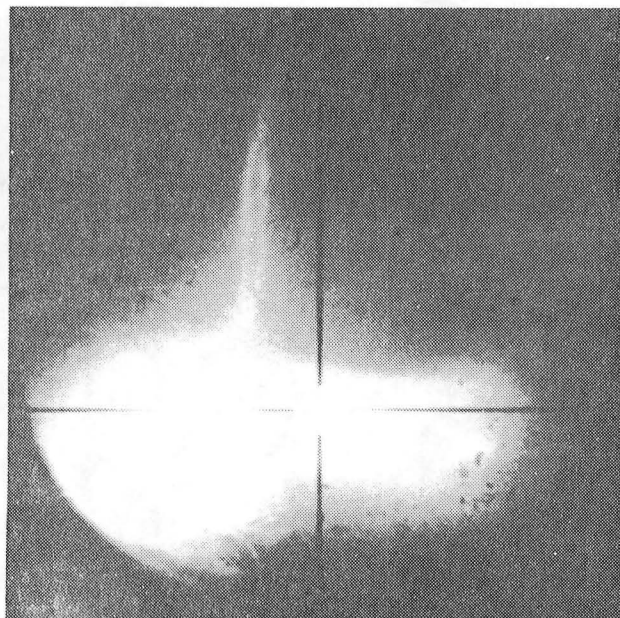
Figure 82.- Lightning attachment point scenario for strike 49,
Flight 82-028



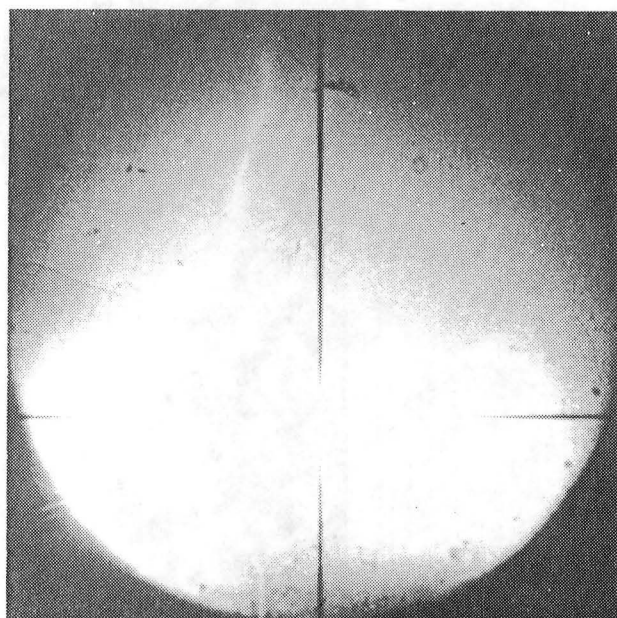
(a) Frame 1 of 7.



(b) Frame 2 of 7.

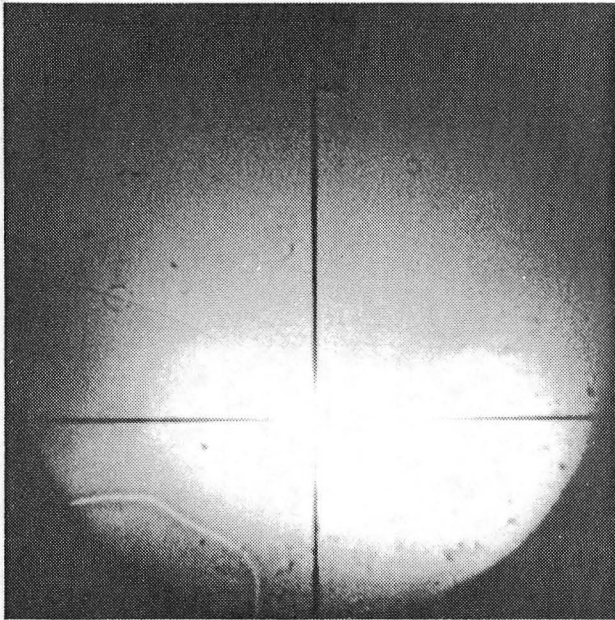


(c) Frame 3 of 7.

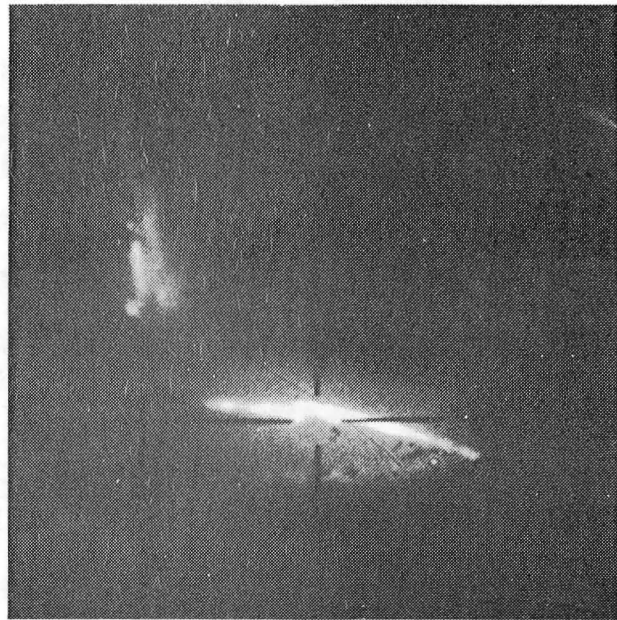


(d) Frame 4 of 7.

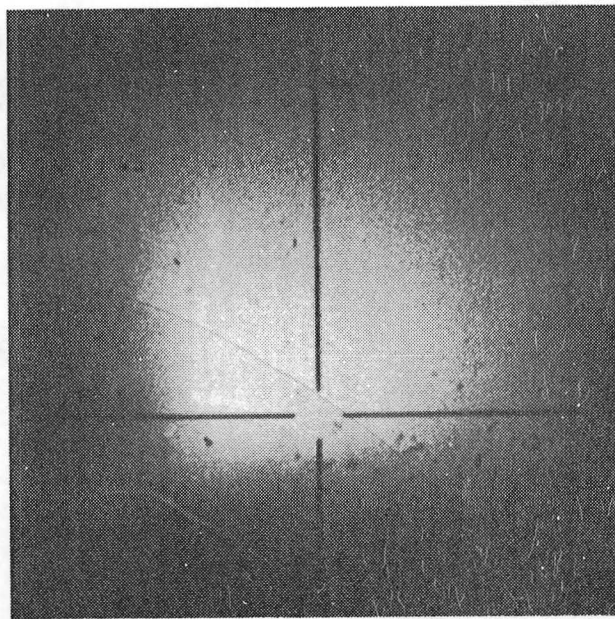
Figure 83. - Strike 49, Flight 82-028, aft camera.



(e) Frame 5 of 7.

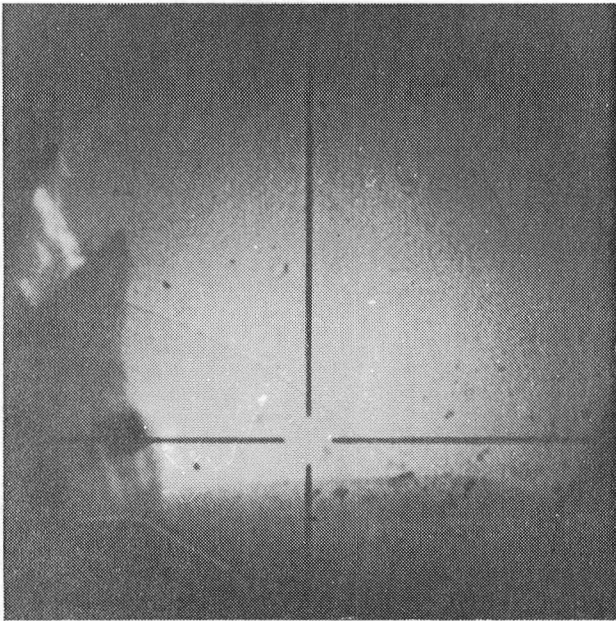


(f) Frame 6 of 7.

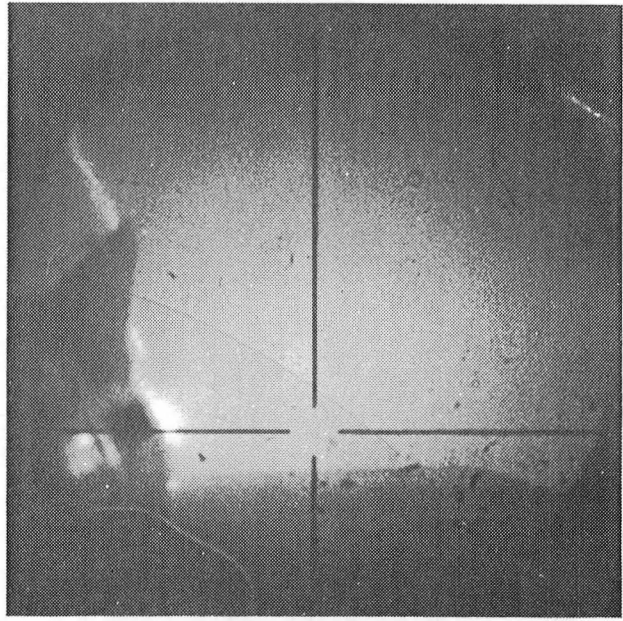


(g) Frame 7 of 7.

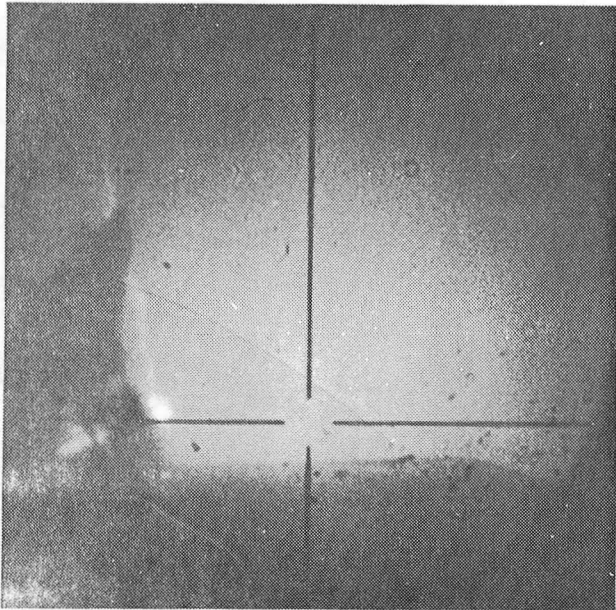
Figure 83. - Concluded.



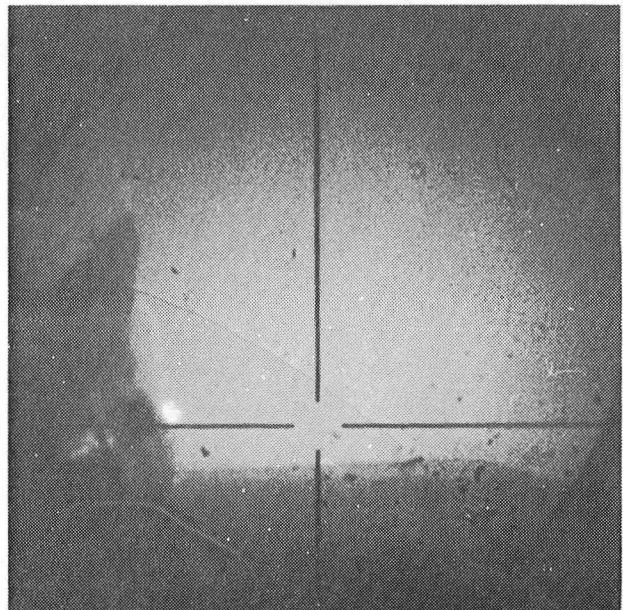
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.

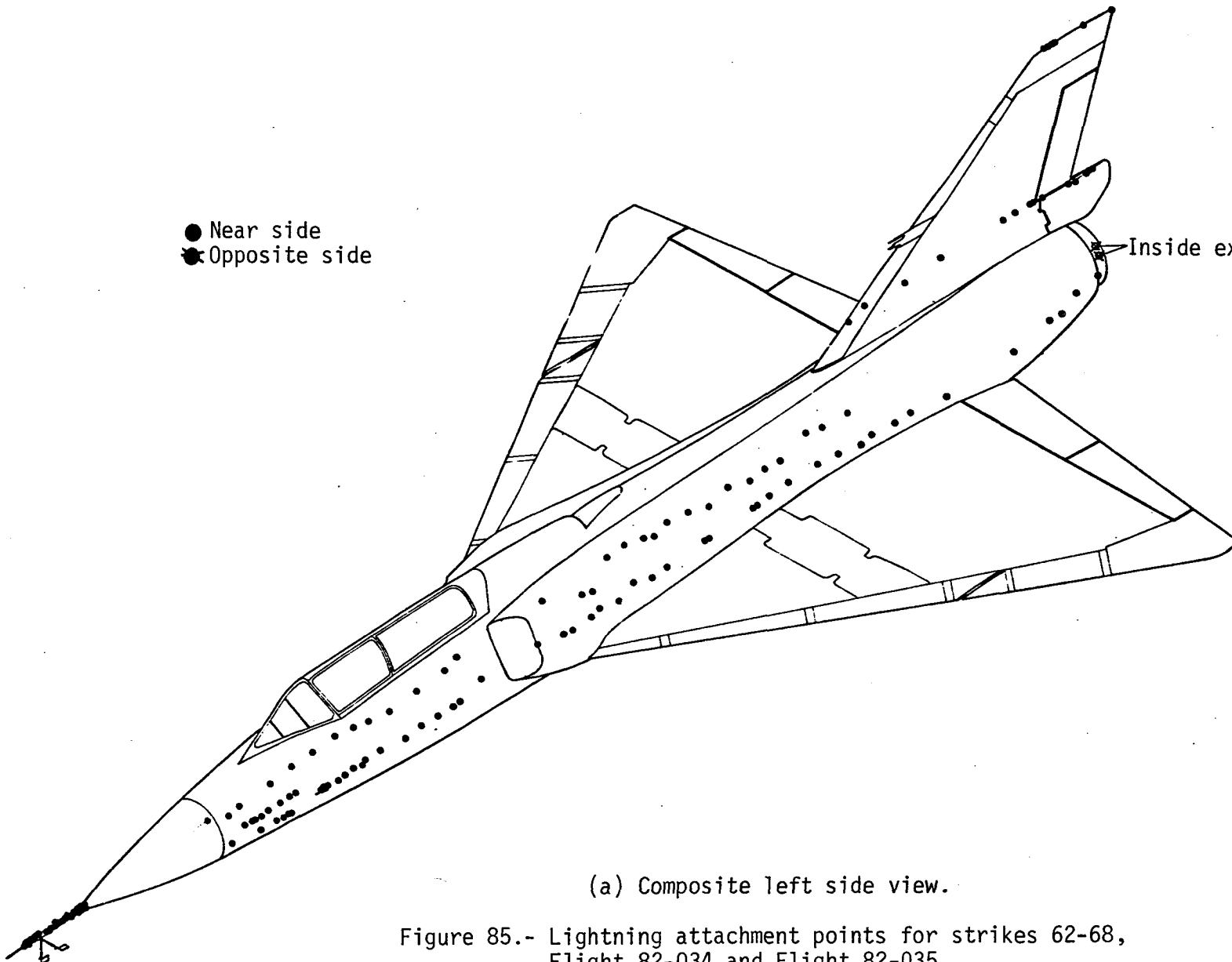


(d) Frame 4 of 4.

Figure 84. - Strike 59, Flight 82-030, aft camera.

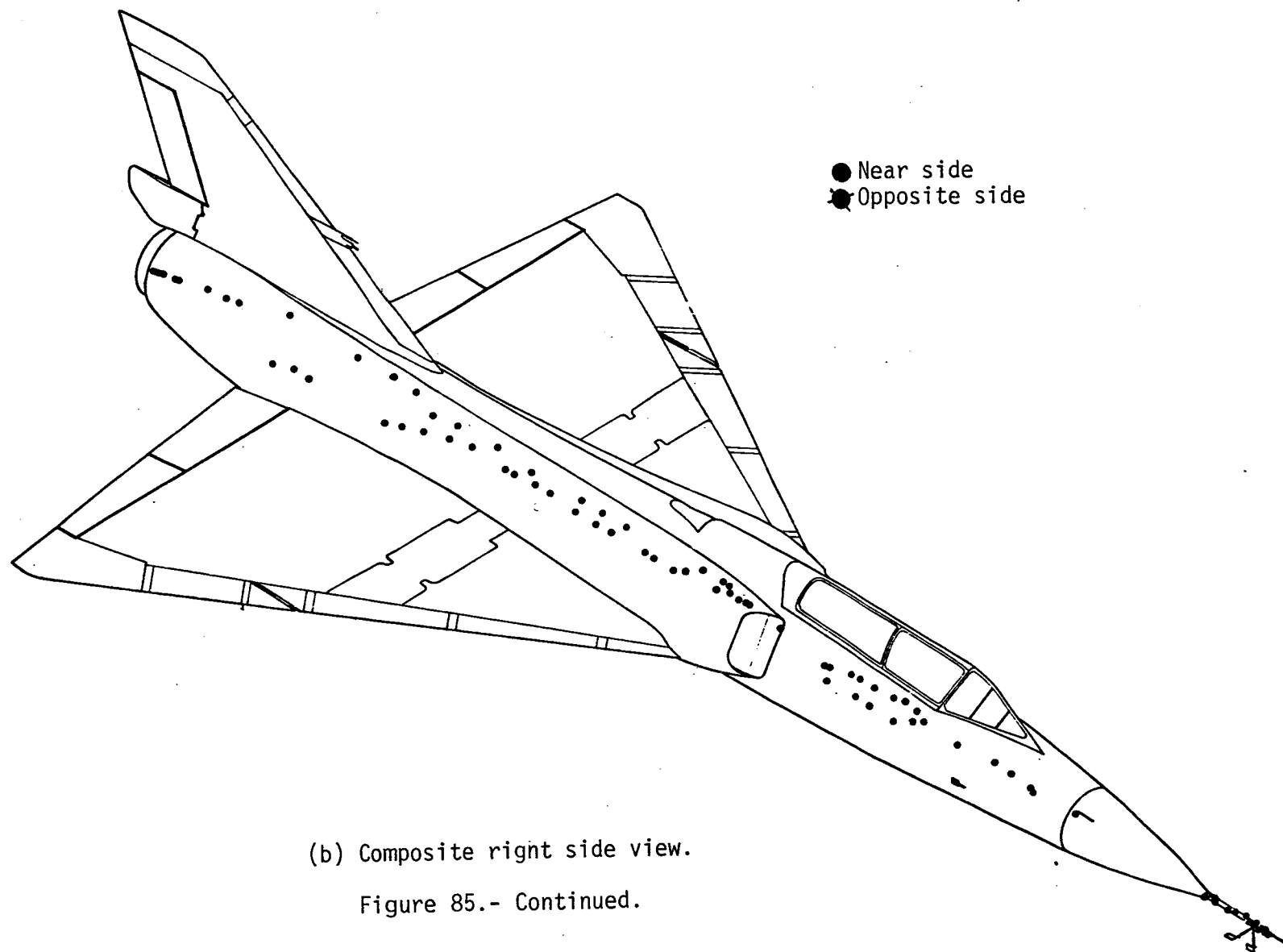
● Near side
✱ Opposite side

Inside exhaust nozzle



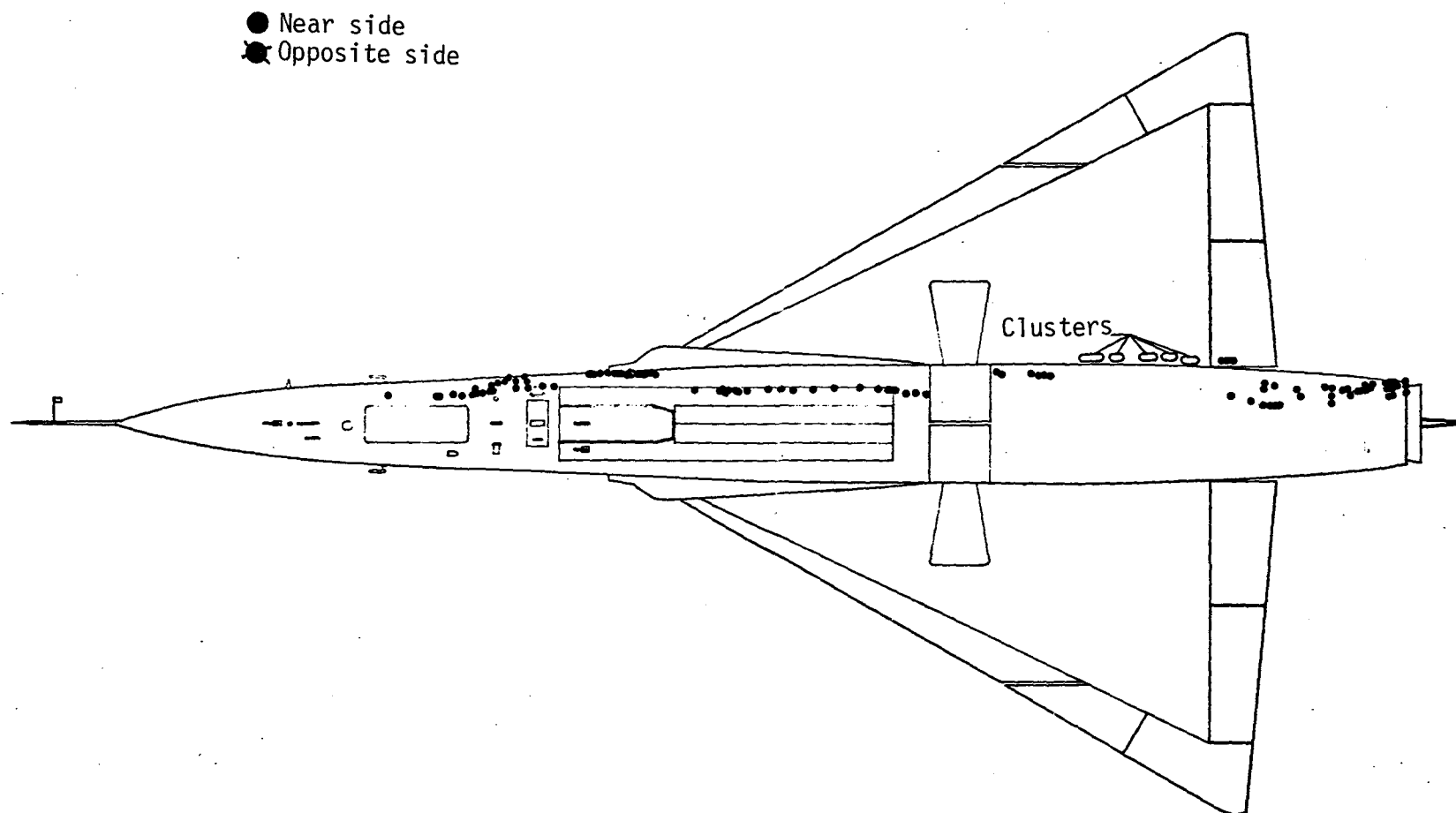
(a) Composite left side view.

Figure 85.- Lightning attachment points for strikes 62-68,
Flight 82-034 and Flight 82-035.



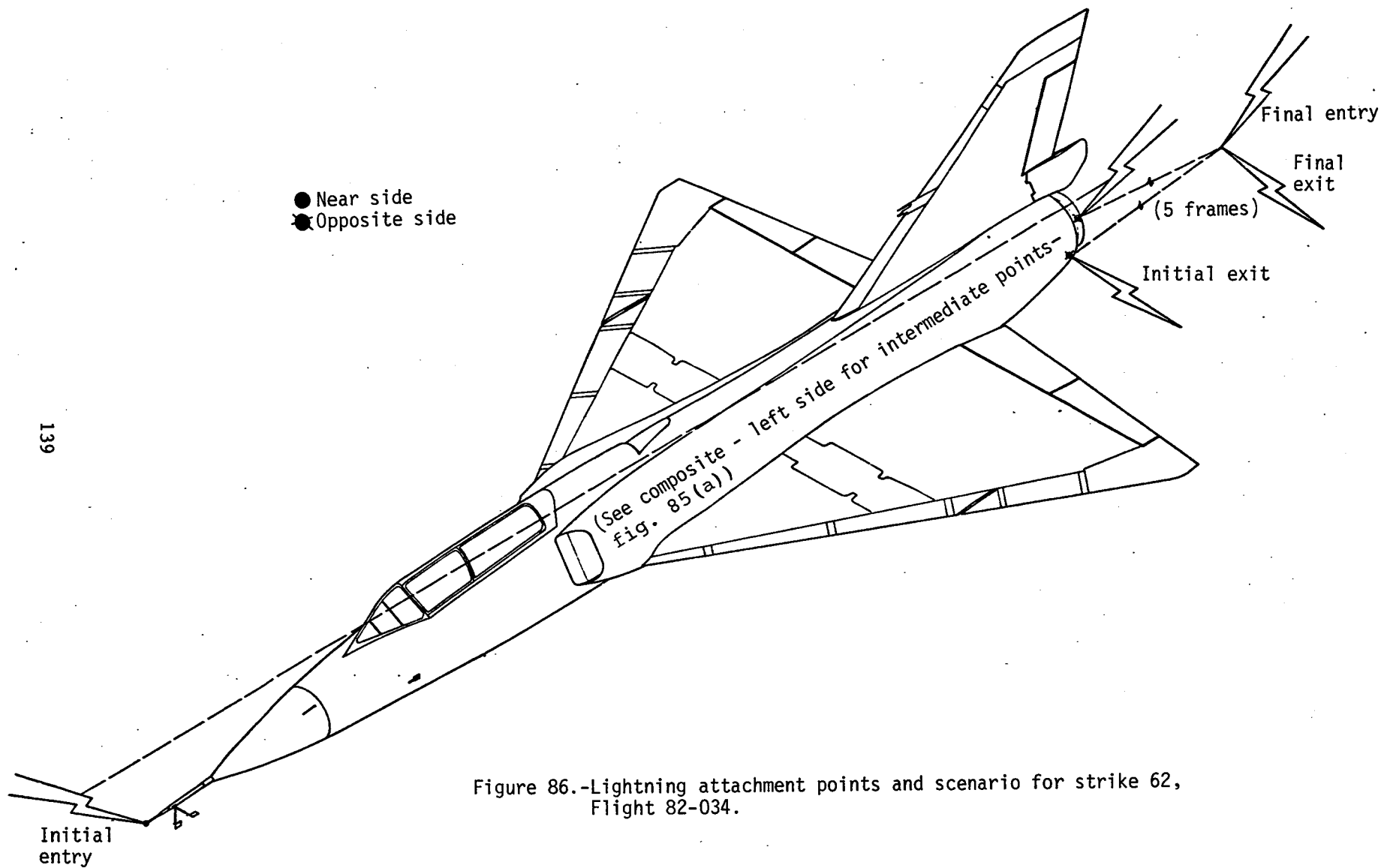
(b) Composite right side view.

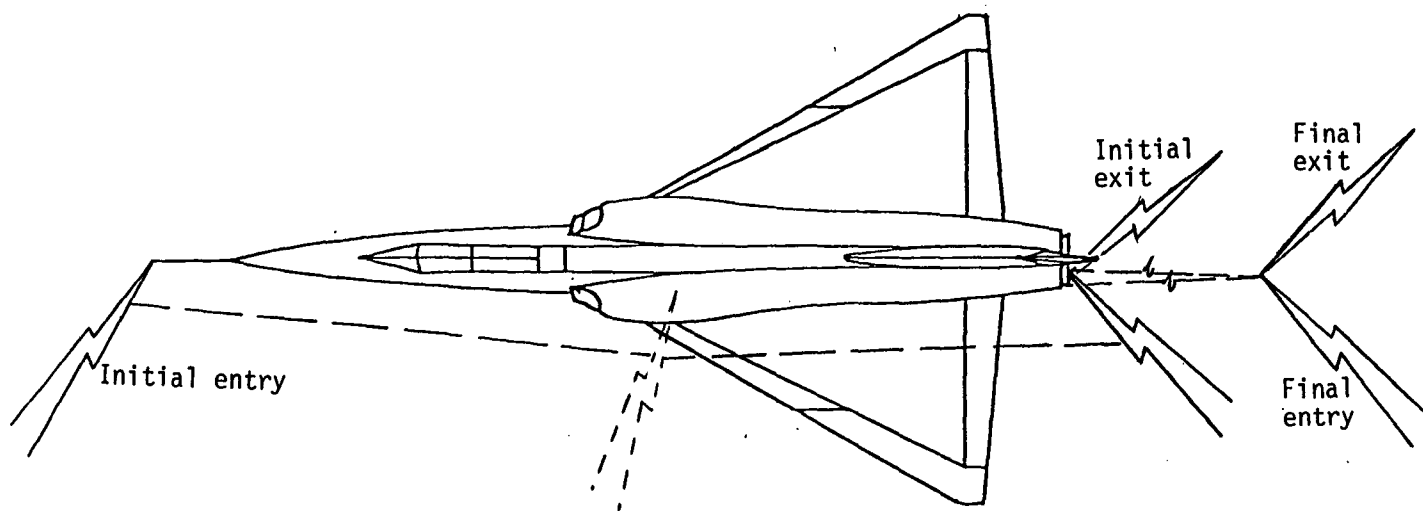
Figure 85.- Continued.



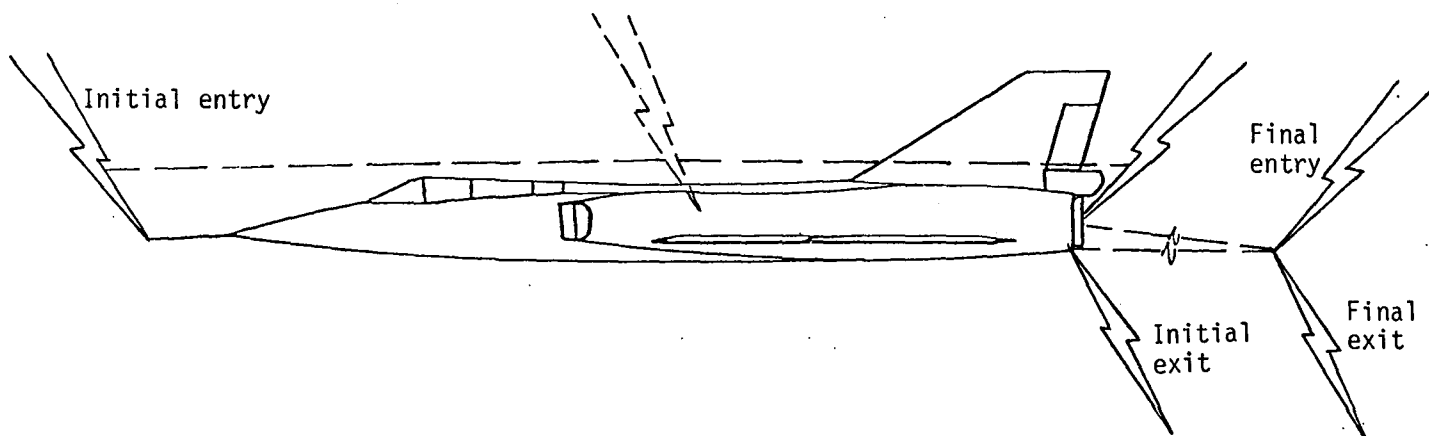
(c) Composite bottom view.

Figure 85.- Concluded.



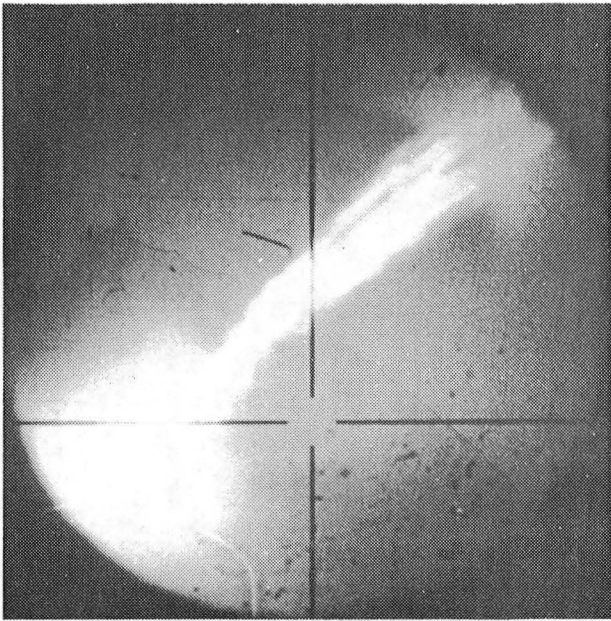


Top view

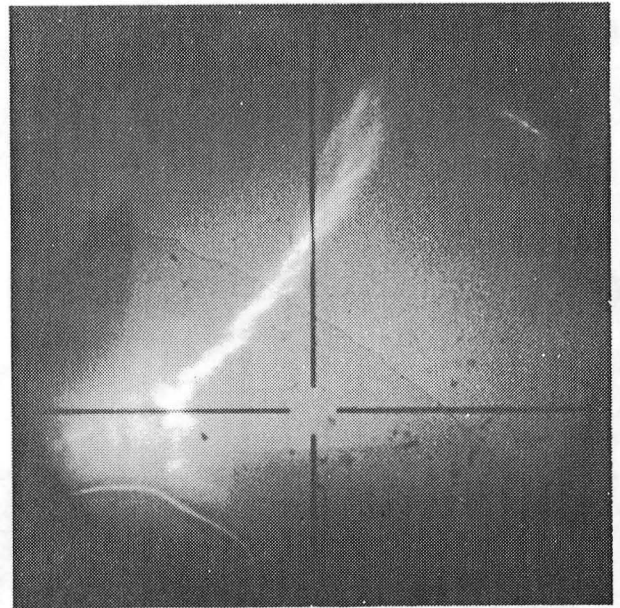


Left side view

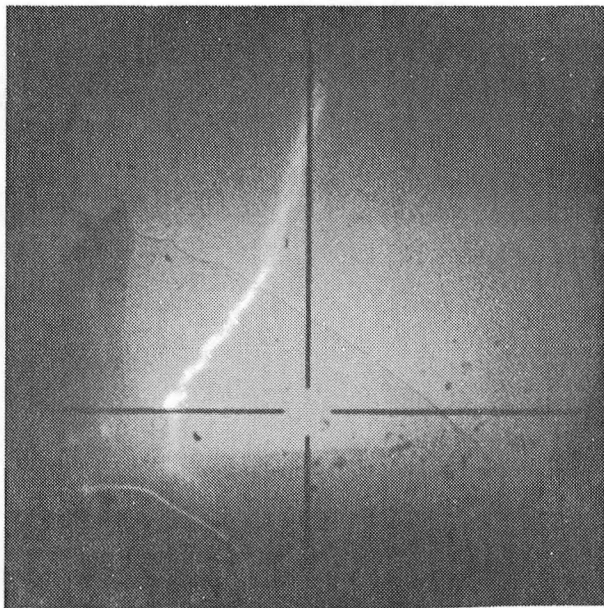
Figure 87.- Lightning attachment point scenario for strike 62, Flight 82-034.



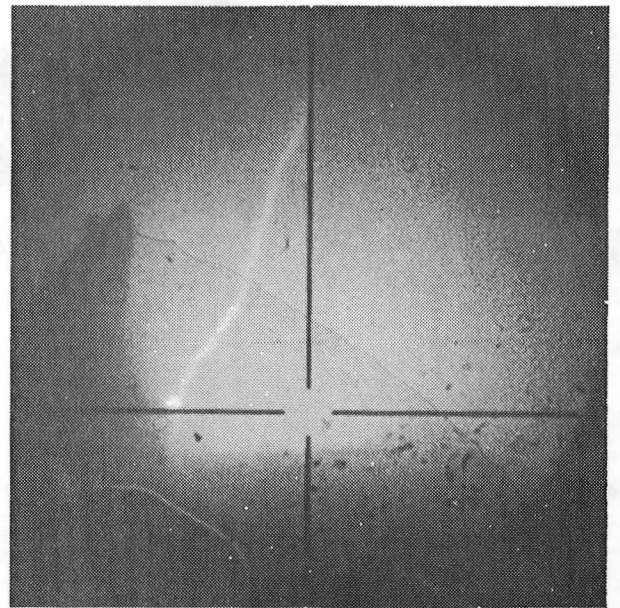
(a) Frame 1 of 5.



(b) Frame 2 of 5.

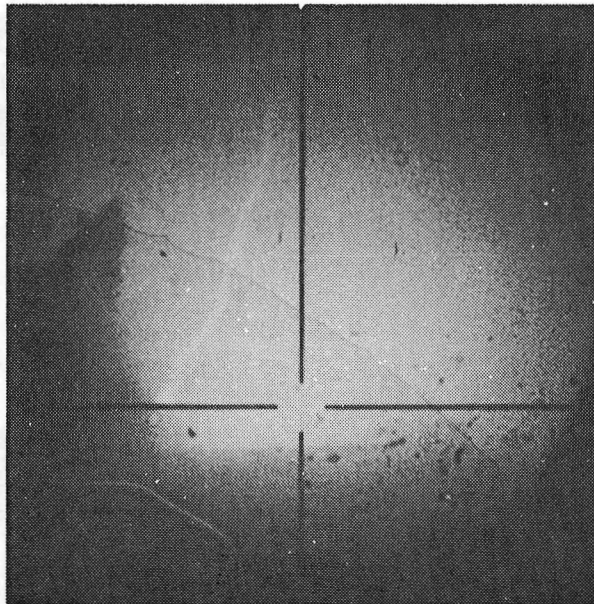


(c) Frame 3 of 5.



(d) Frame 4 of 5.

Figure 88. - Strike 62, Flight 82-034, aft camera.



(e) Frame 5 of 5.

Figure 88. - Concluded.

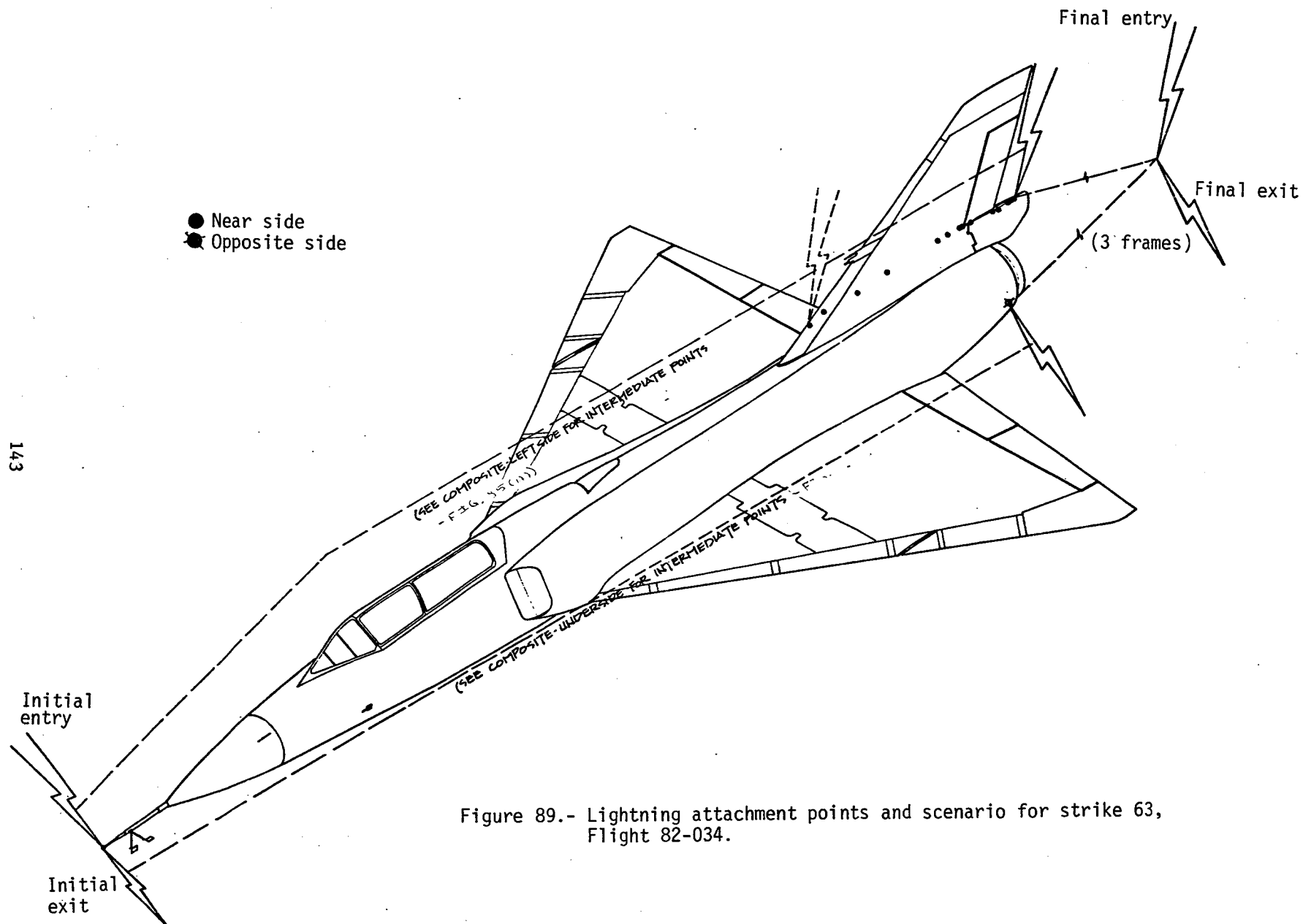
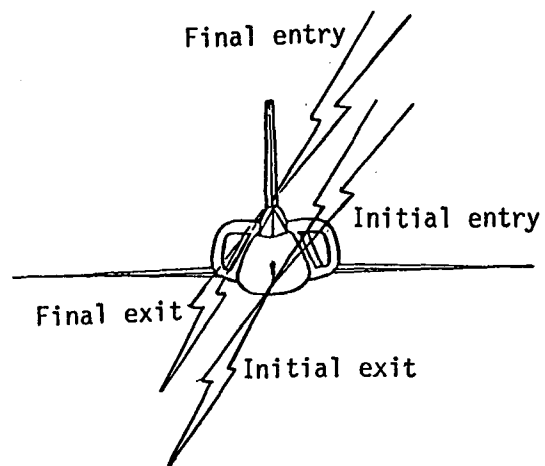
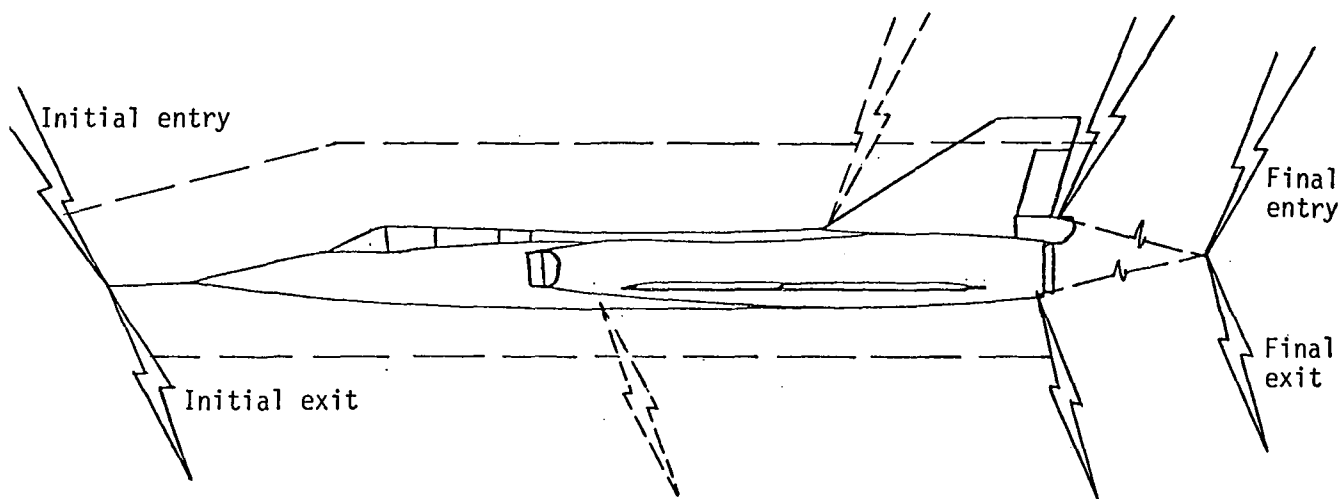


Figure 89.- Lightning attachment points and scenario for strike 63, Flight 82-034.

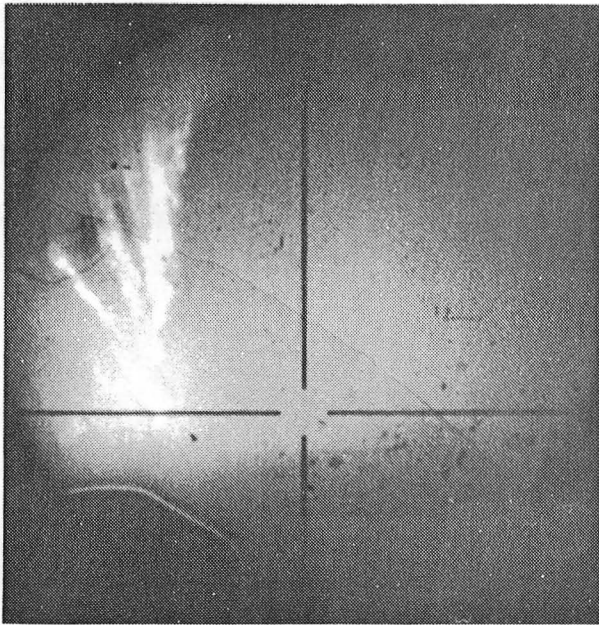


Front view

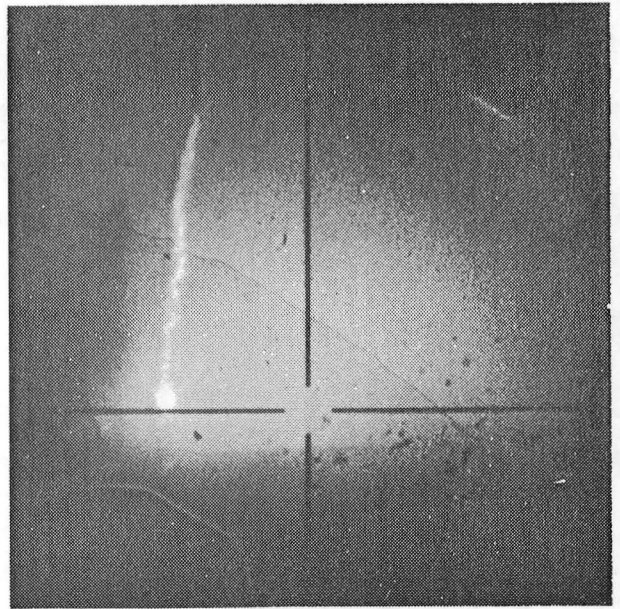


Left side view

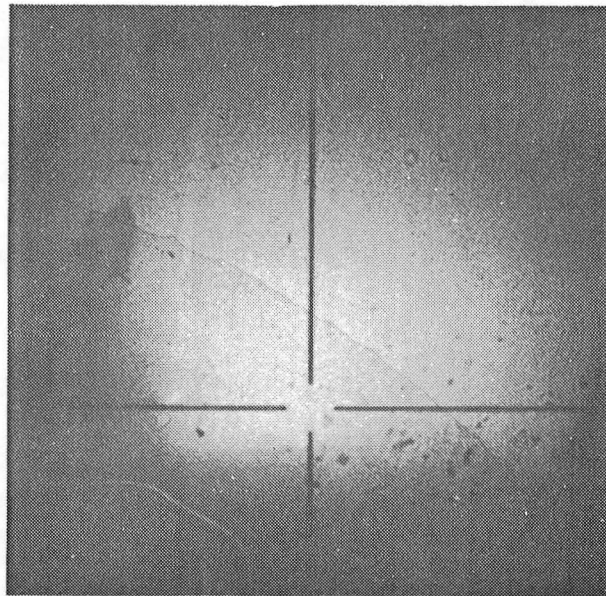
Figure 90.- Lightning attachment point scenario for strike 63,
Flight 82- 034.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 91. - Strike 63, Flight 82-034, aft camera.

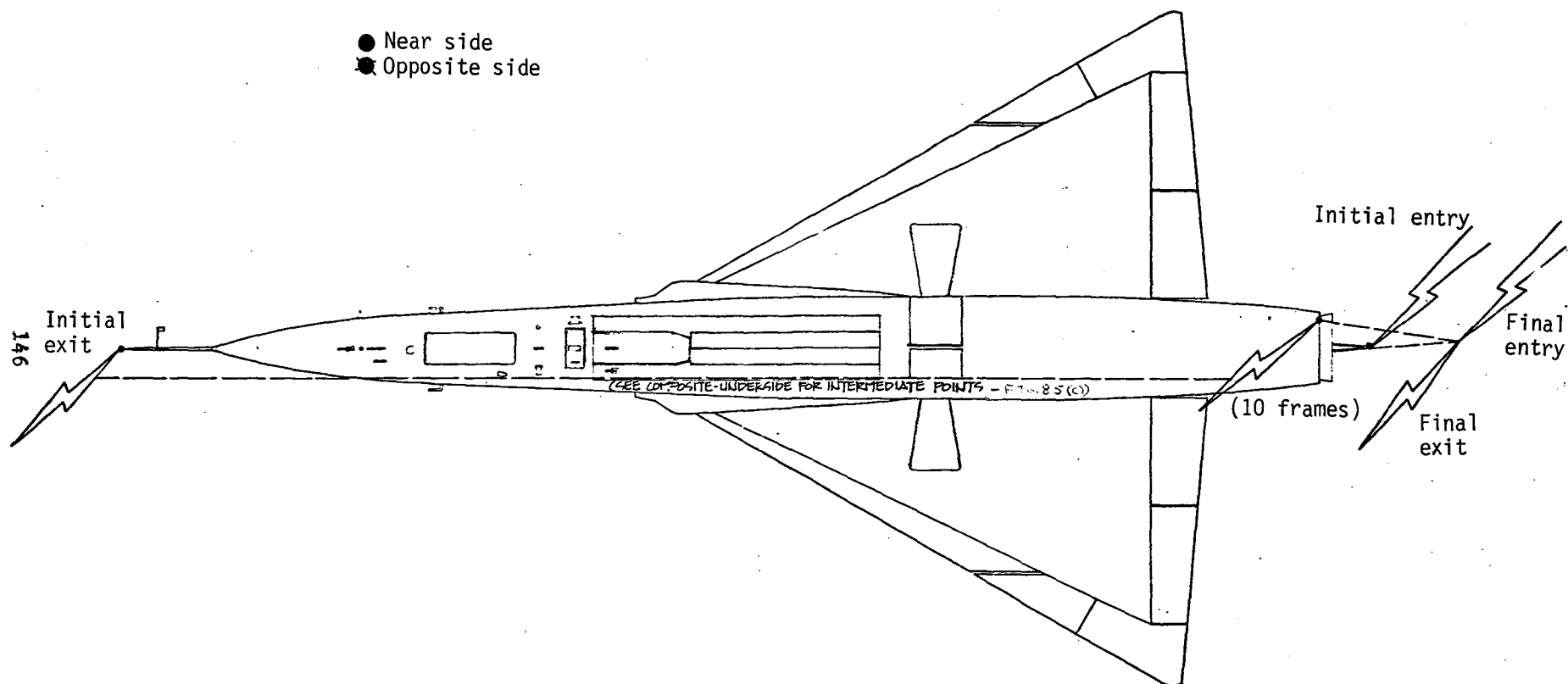
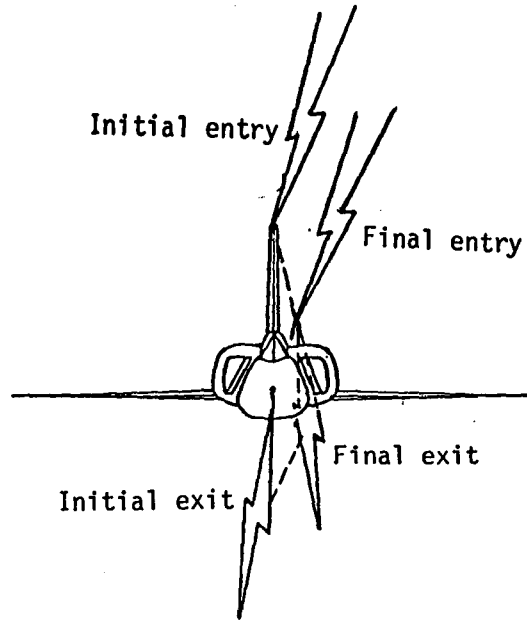
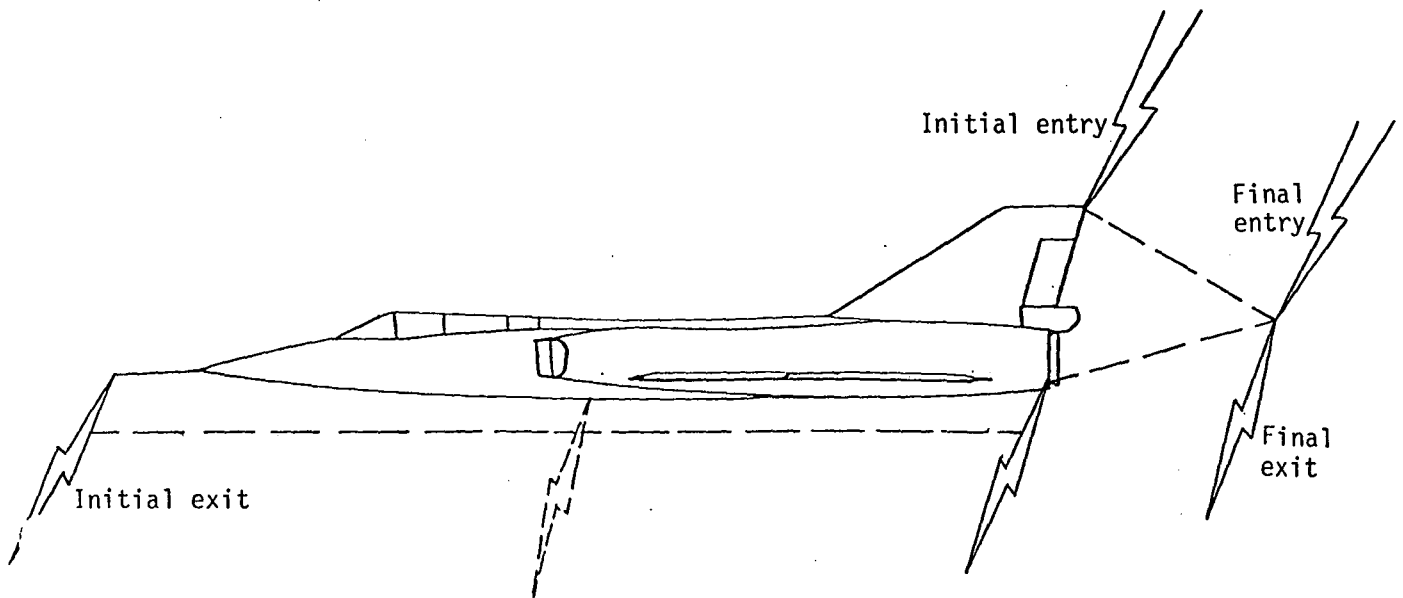


Figure 92.- Lightning attachment points and scenario for strike 65, Flight 82-034.

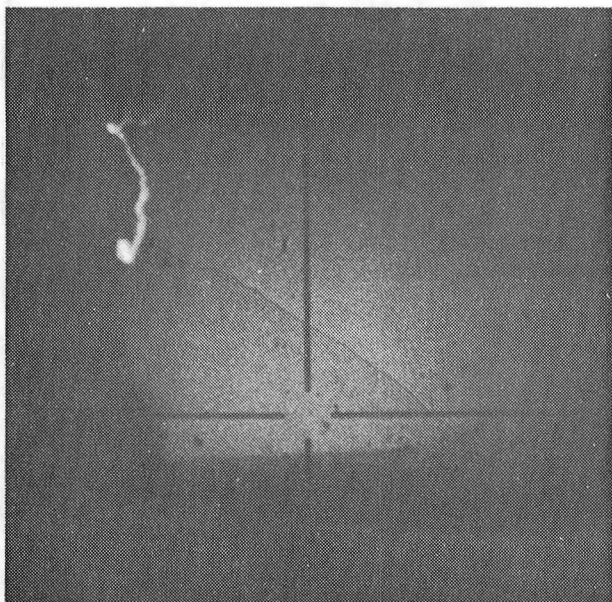


Front view

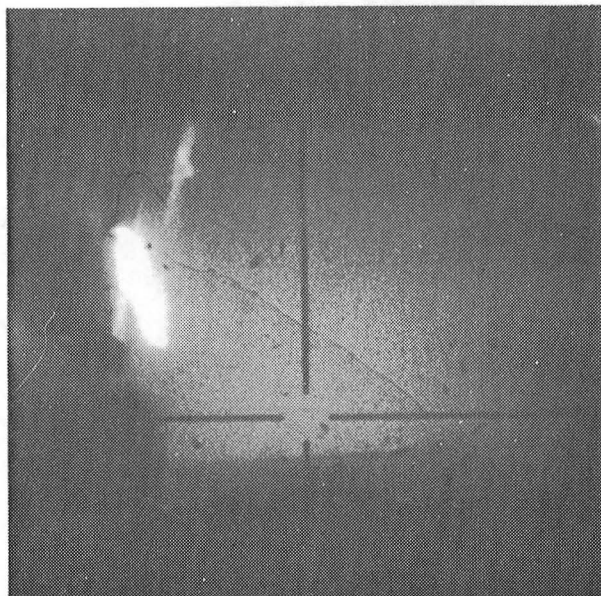


Left side view

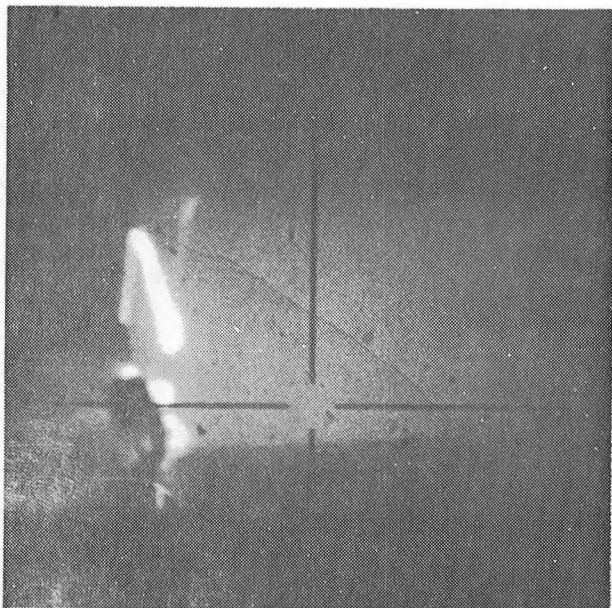
Figure 93.- Lightning attachment point scenario for strike 65, Flight 82-034.



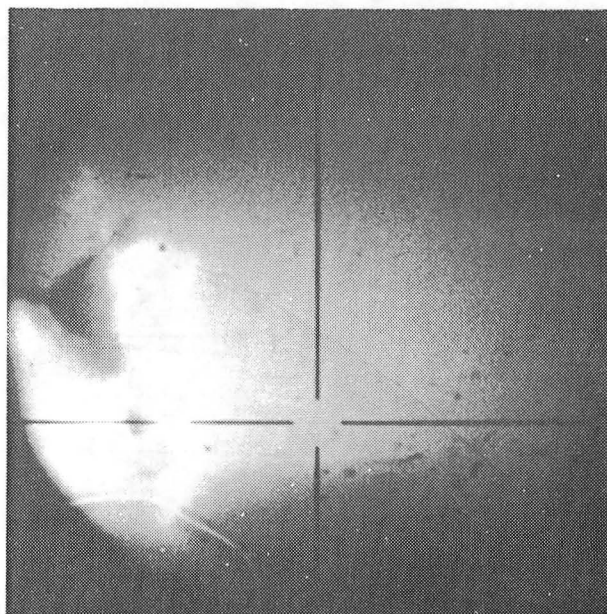
(a) Frame 1 of 10.



(b) Frame 2 of 10.

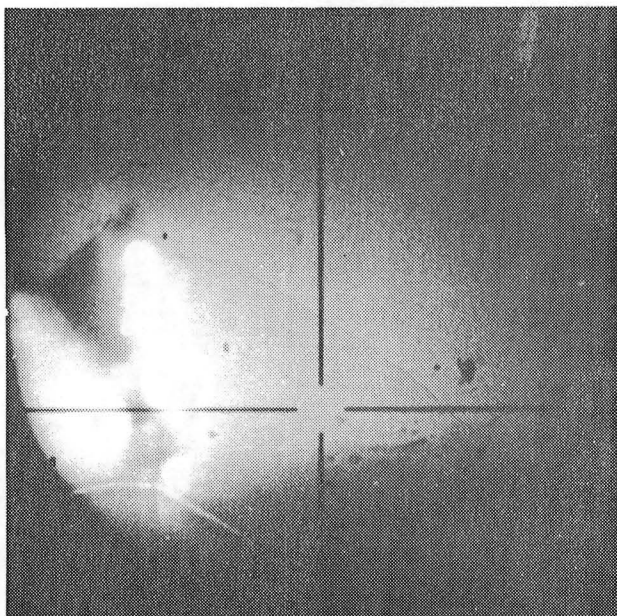


(c) Frame 3 of 10.

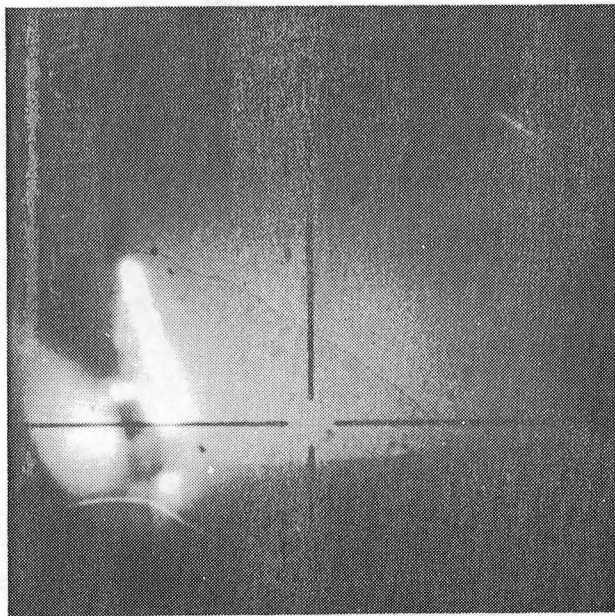


(d) Frame 4 of 10.

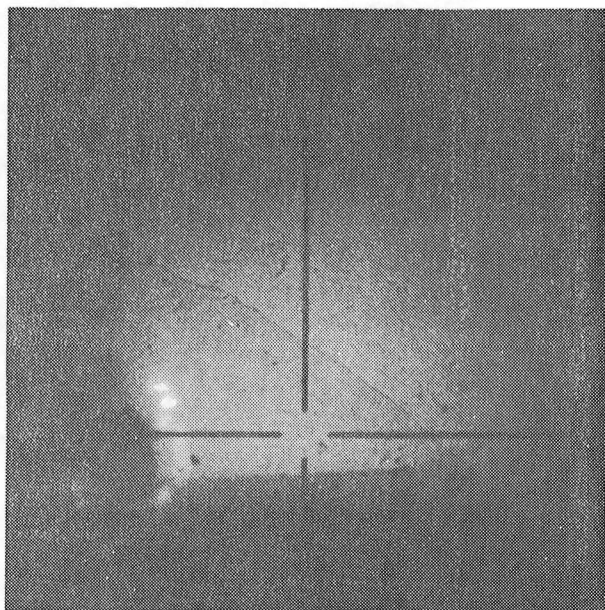
Figure 94. - Strike 65, Flight 82-034, aft camera.



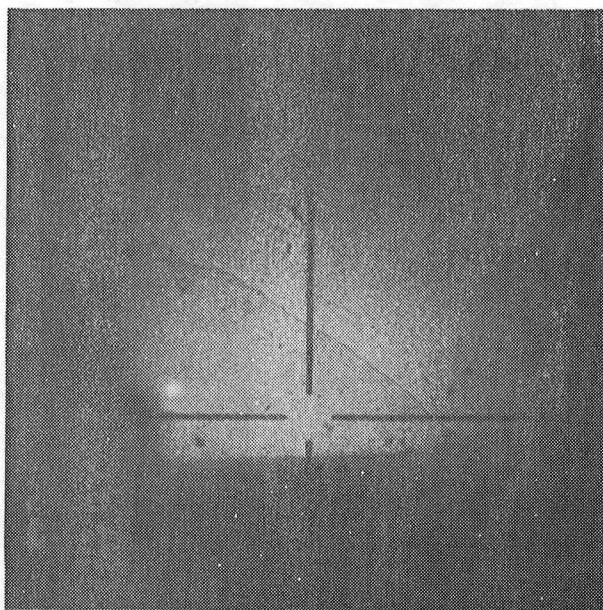
(e) Frame 5 of 10.



(f) Frame 6 of 10.

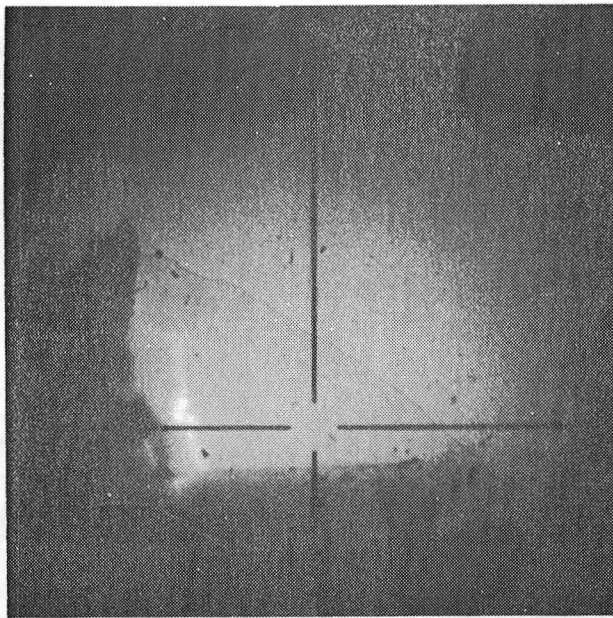


(g) Frame 7 of 10.

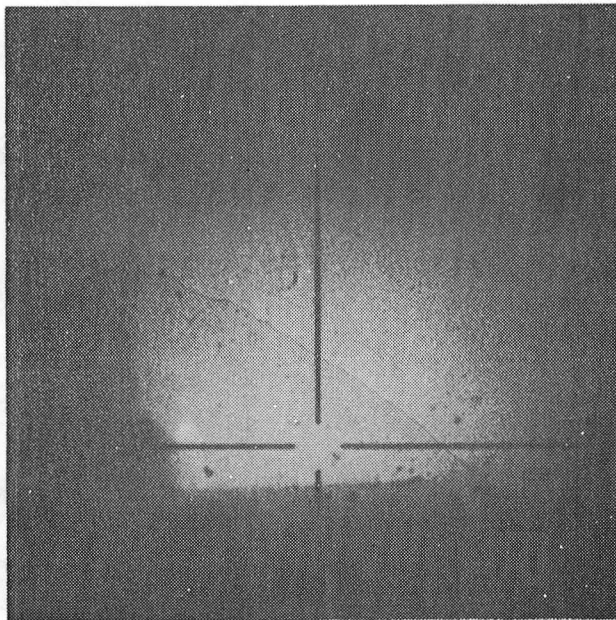


(h) Frame 8 of 10.

Figure 94. - Continued.



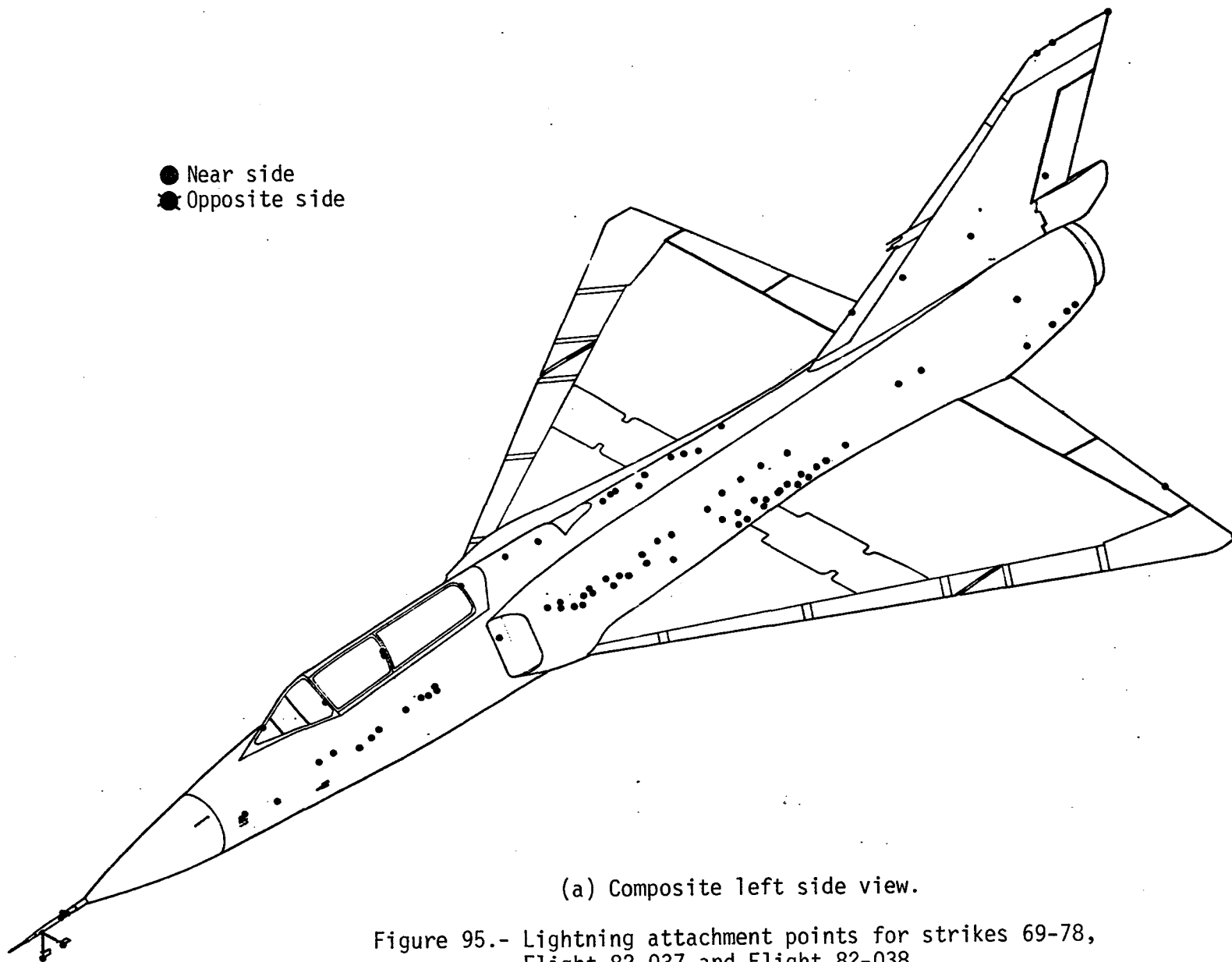
(i) Frame 9 of 10.



(j) Frame 10 of 10.

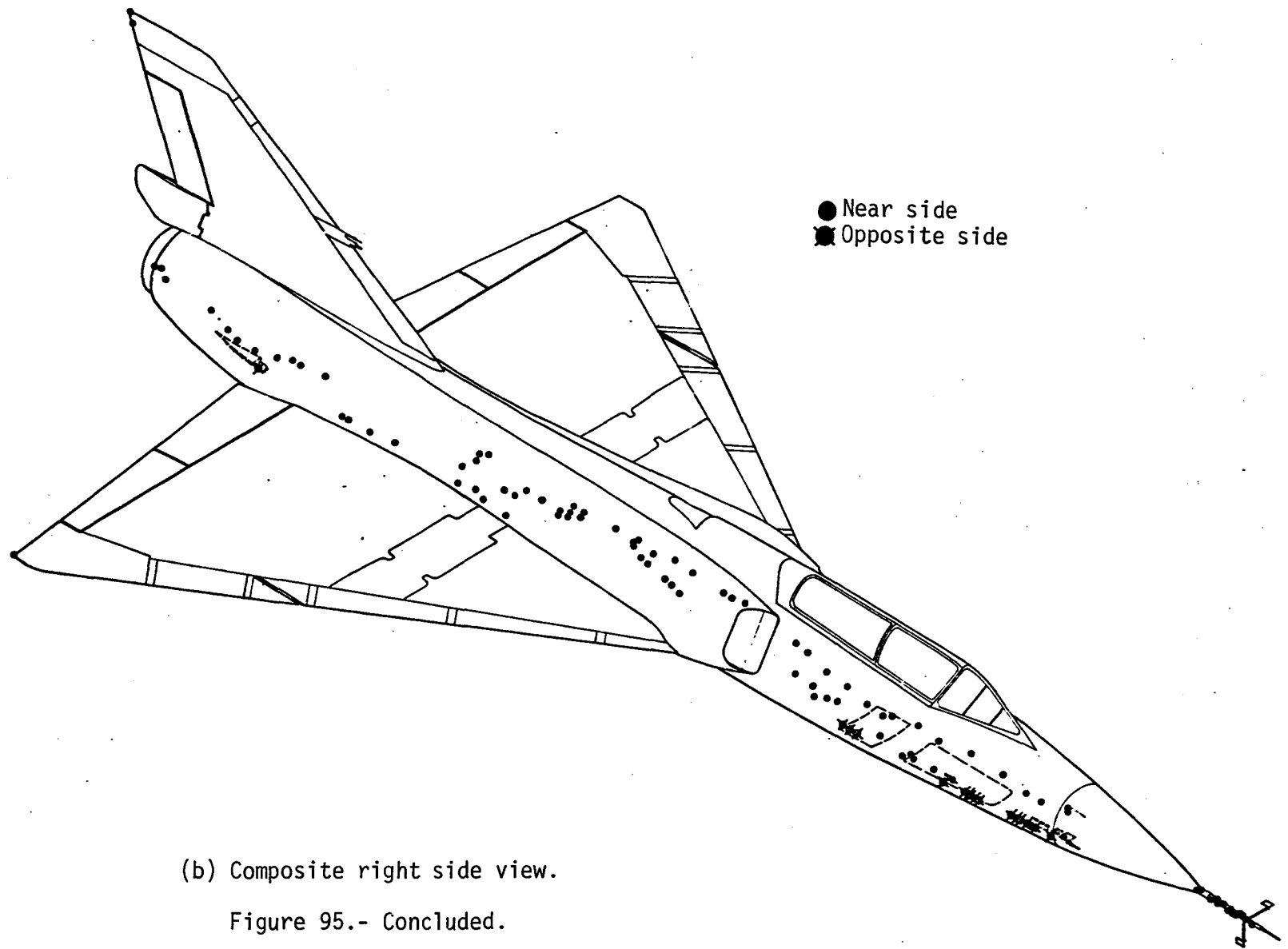
Figure 94. - Concluded.

● Near side
● Opposite side



(a) Composite left side view.

Figure 95.- Lightning attachment points for strikes 69-78,
Flight 82-037 and Flight 82-038.



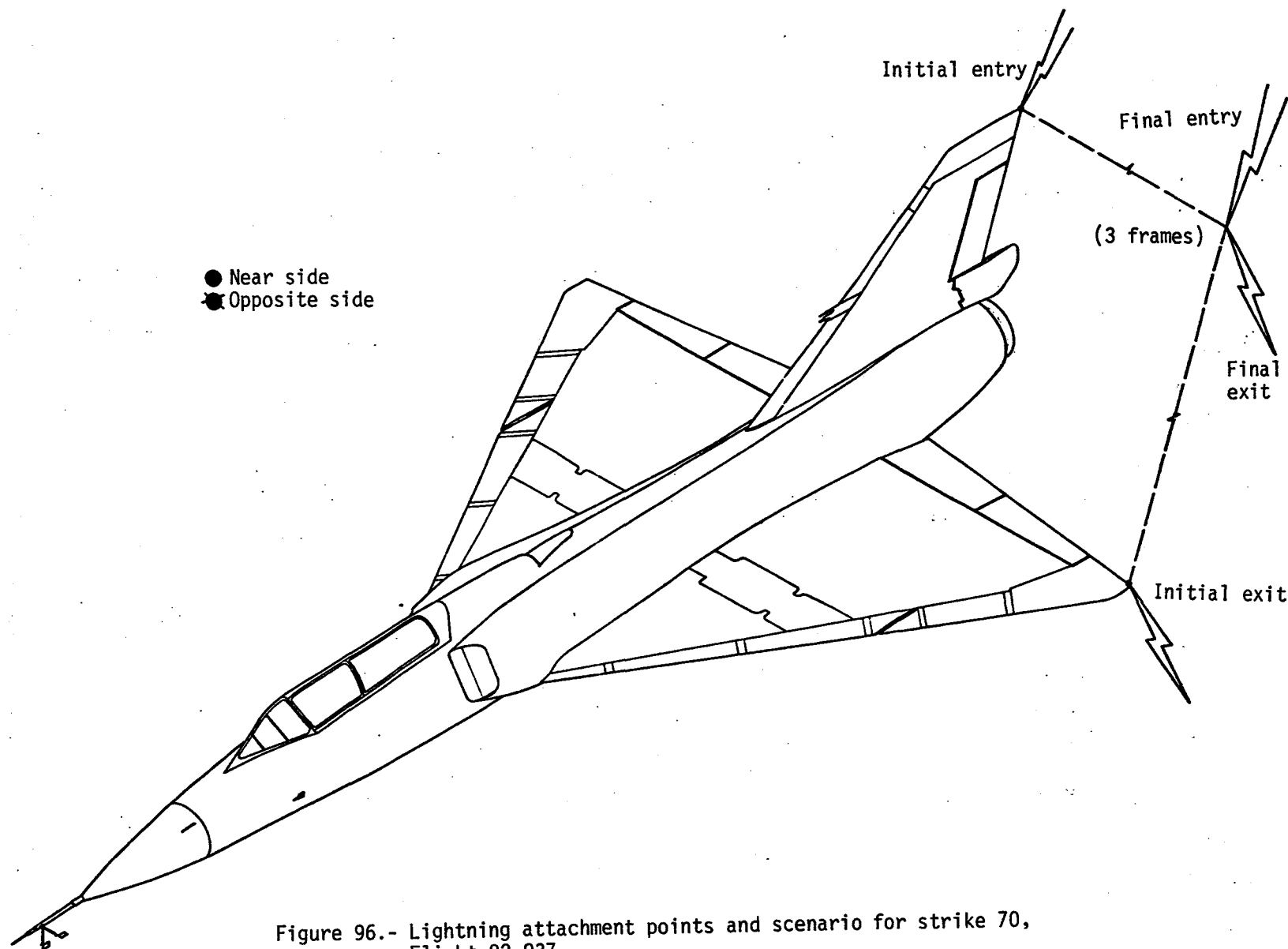


Figure 96.- Lightning attachment points and scenario for strike 70, Flight 82-037.

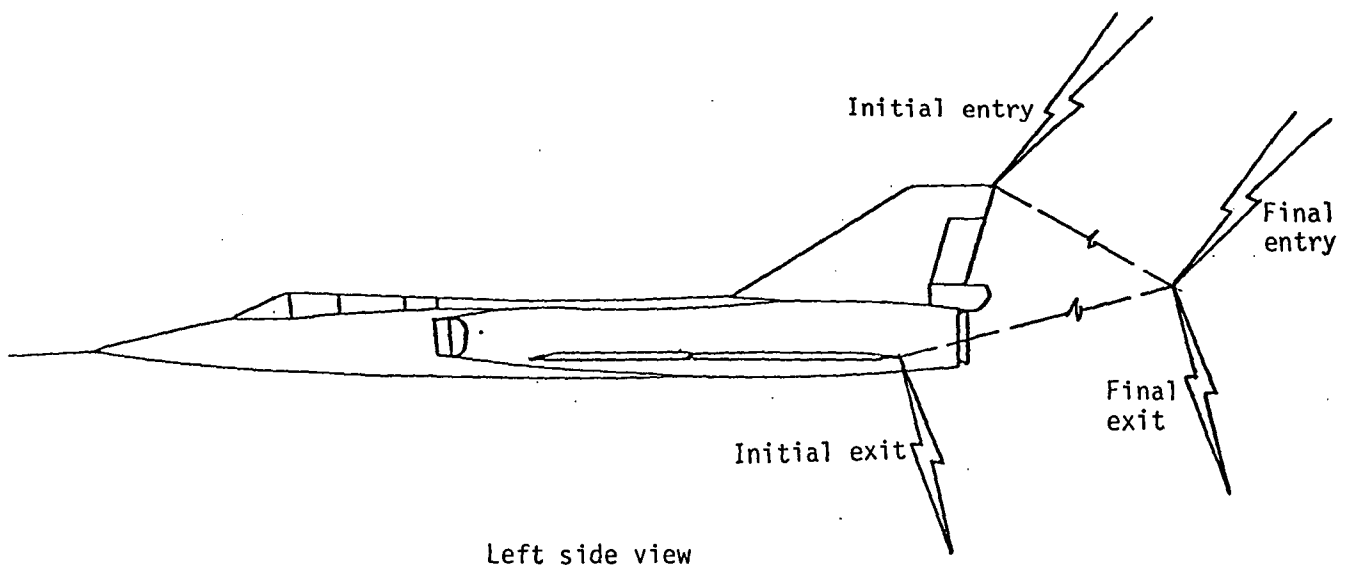
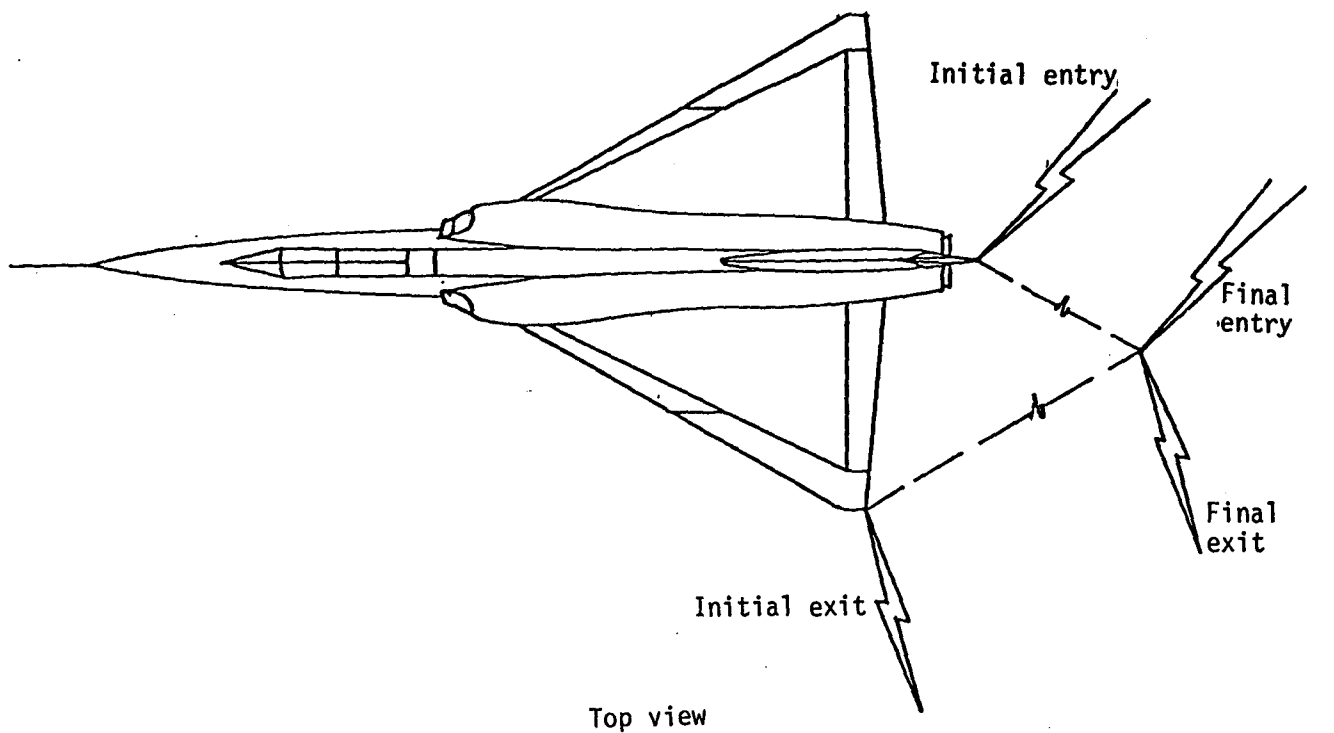
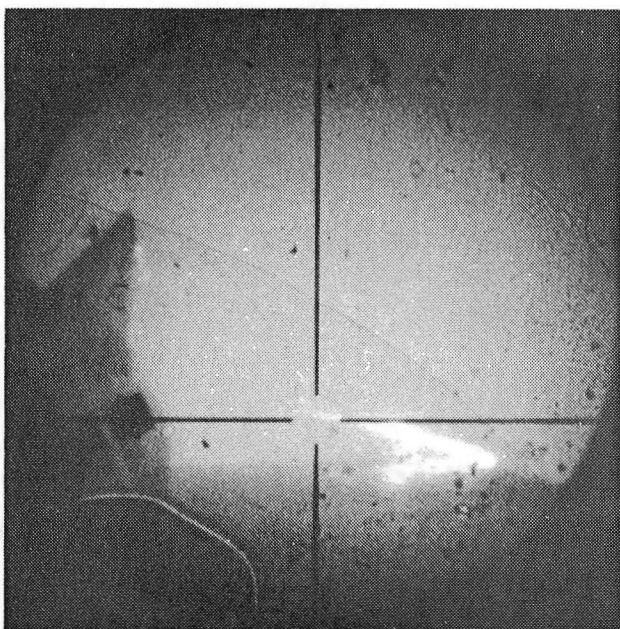
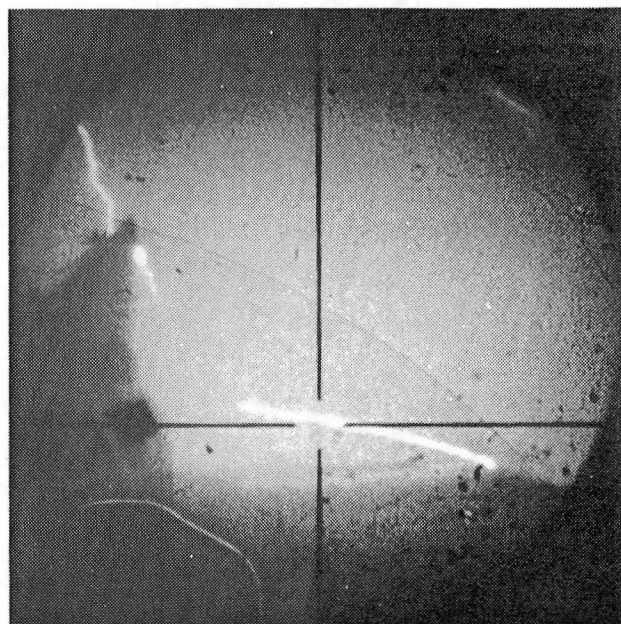


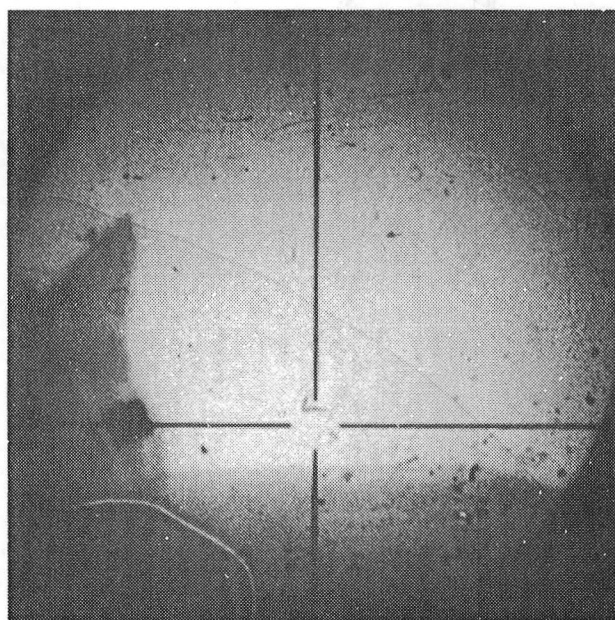
Figure 97.- Lightning attachment point scenario for strike 70,
Flight 82-037.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 98. - Strike 70, Flight 82-037, aft camera.

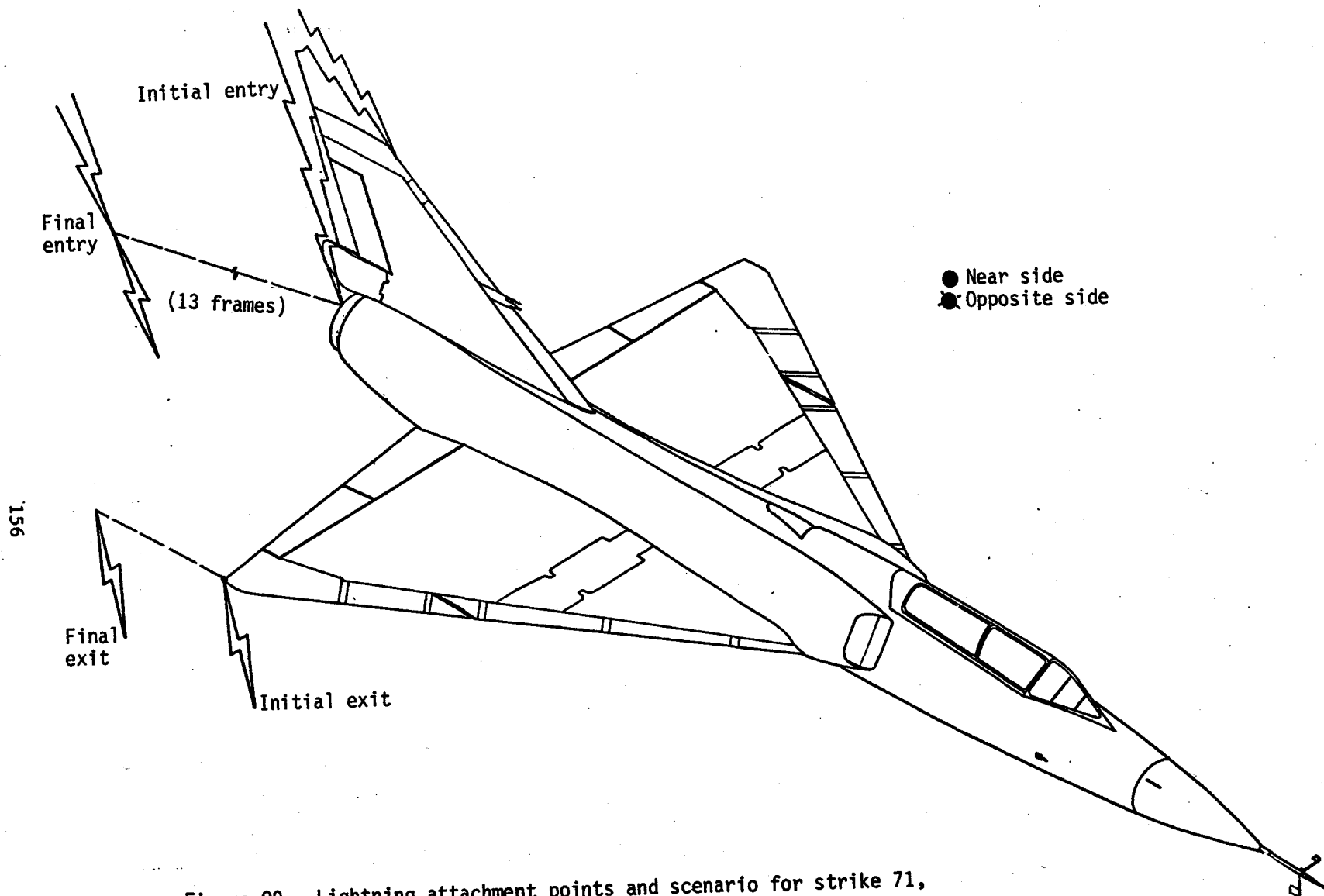


Figure 99.- Lightning attachment points and scenario for strike 71, Flight 82-038.

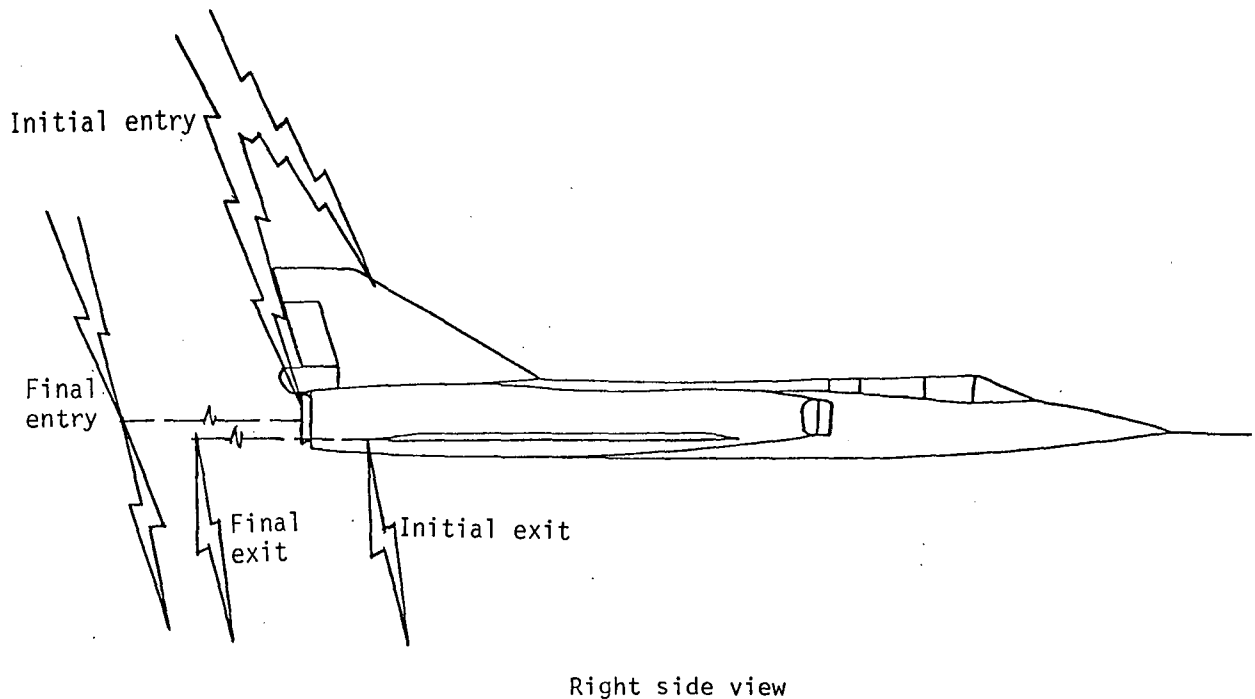
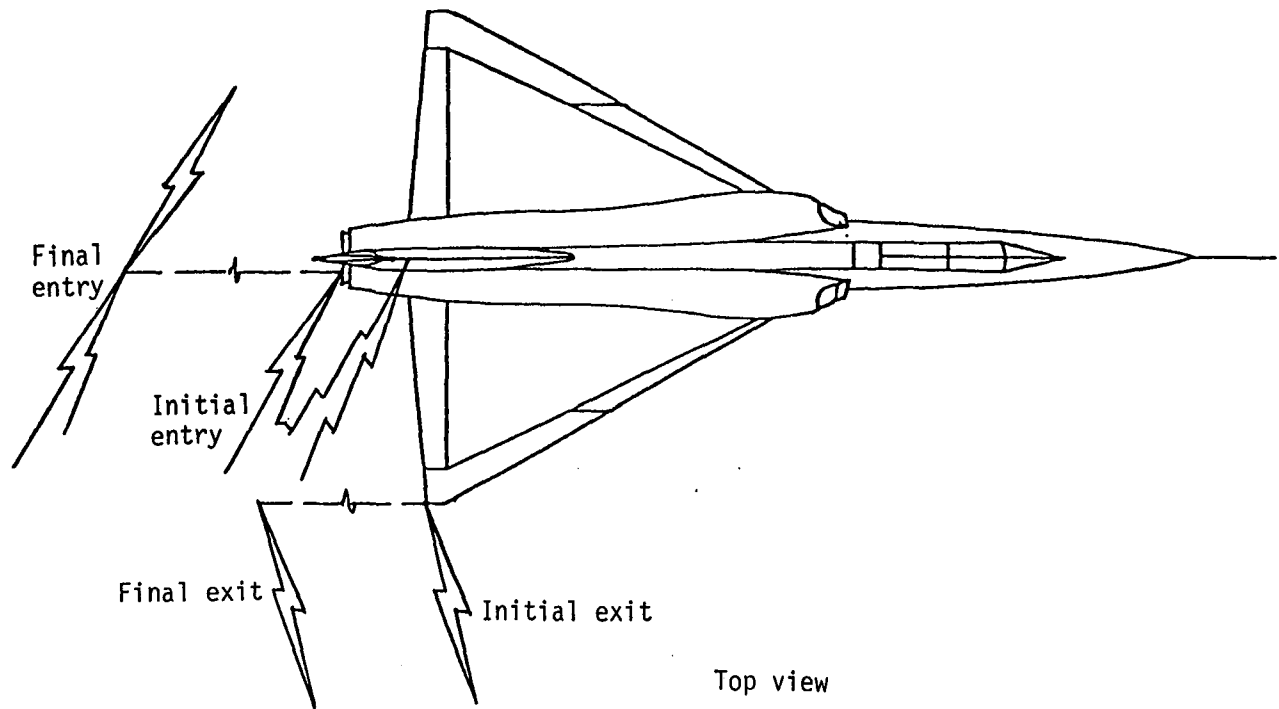
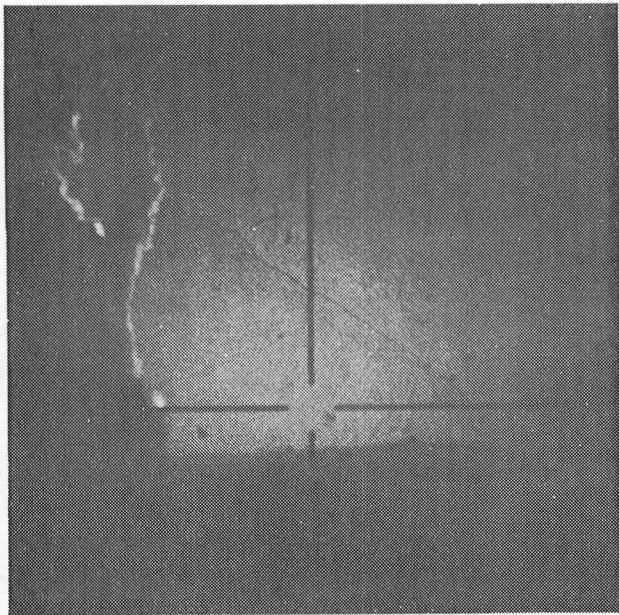
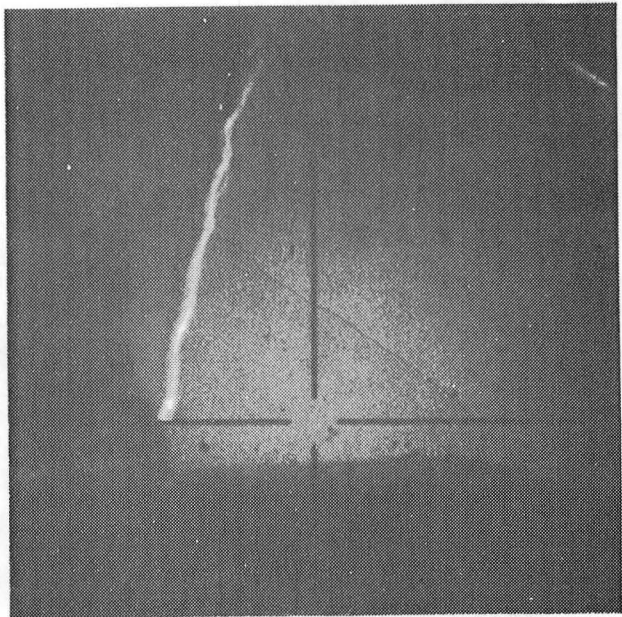


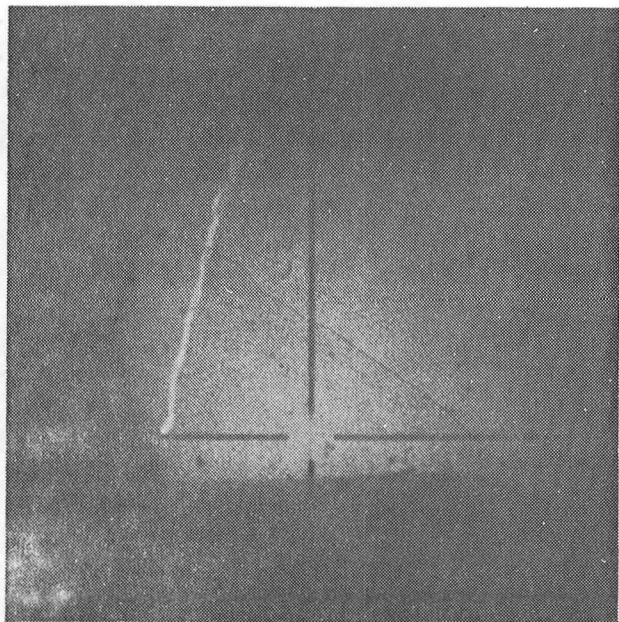
Figure 100.- Lightning attachment point scenario for strike 71, Flight 82-038.



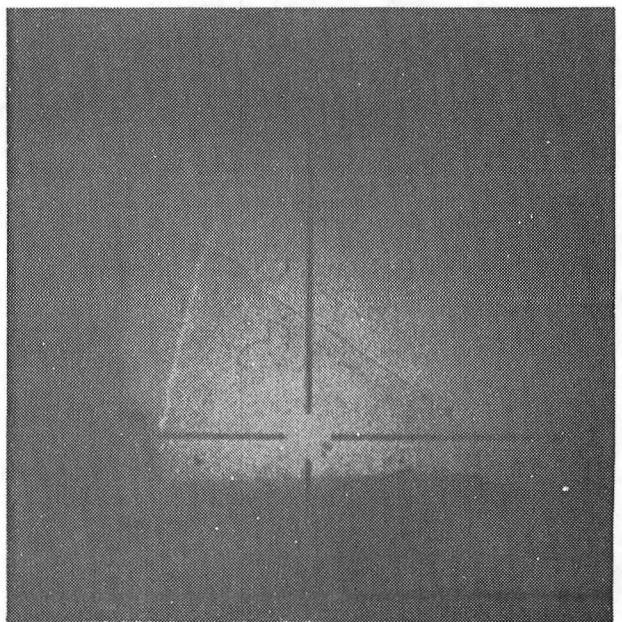
(a) Frame 1 of 13.



(b) Frame 2 of 13.

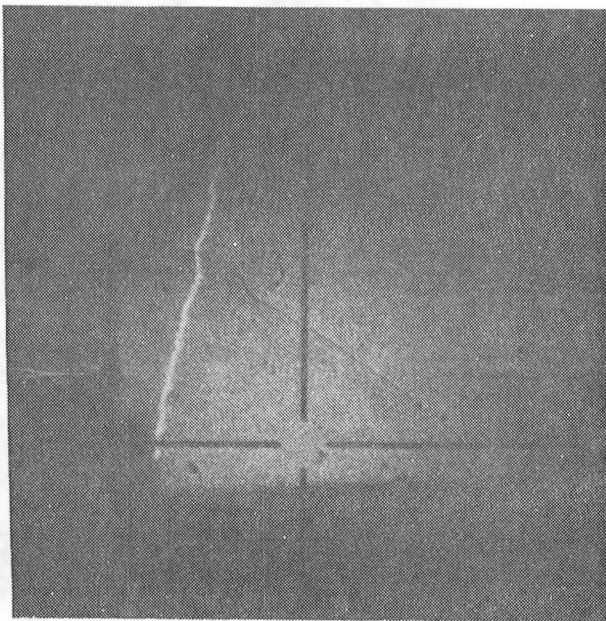


(c) Frame 3 of 13.

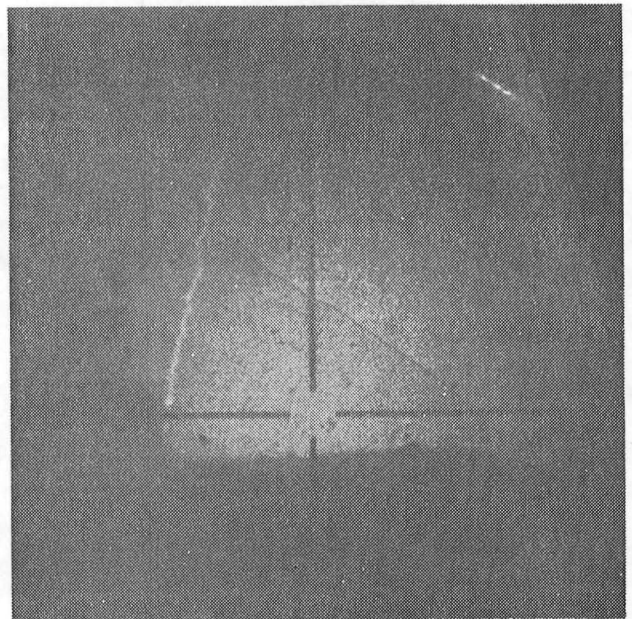


(d) Frame 4 of 13.

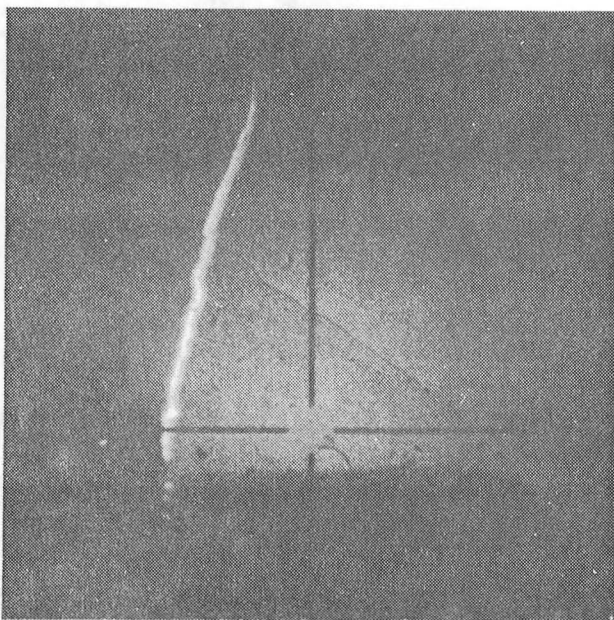
Figure 101. - Strike 71, Flight 82-038, aft camera.



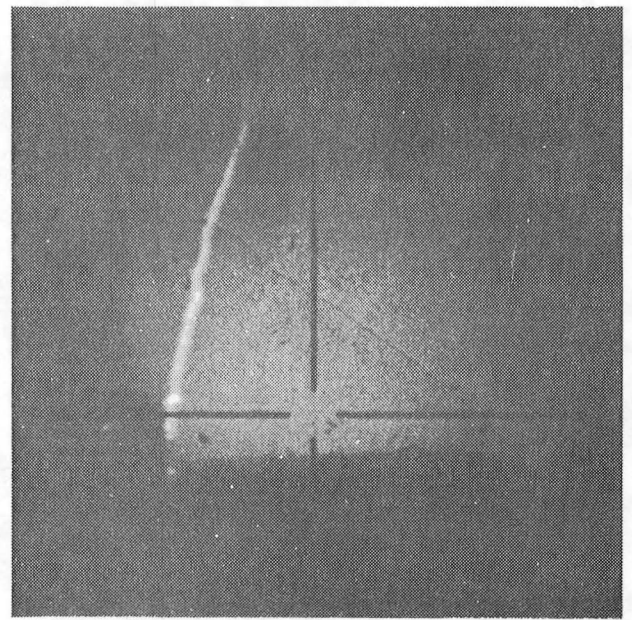
(e) Frame 5 of 13.



(f) Frame 6 of 13.

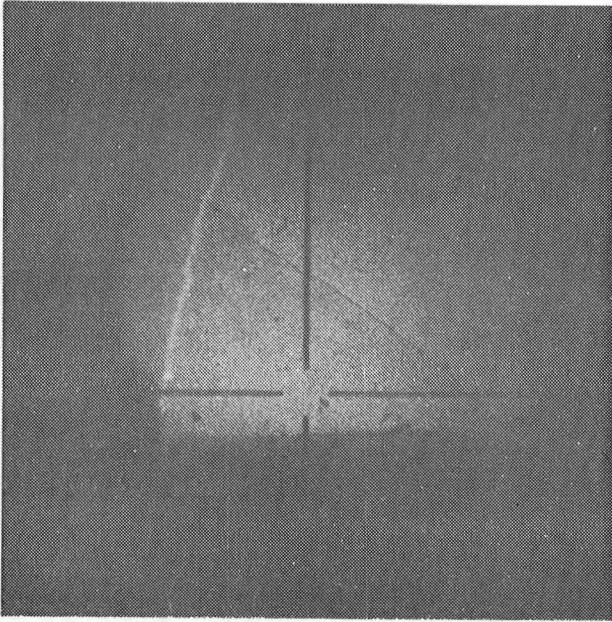


(g) Frame 7 of 13.

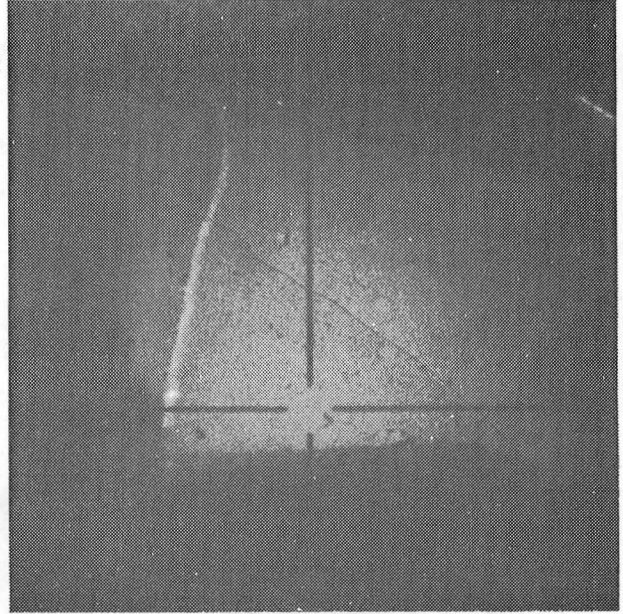


(h) Frame 8 of 13.

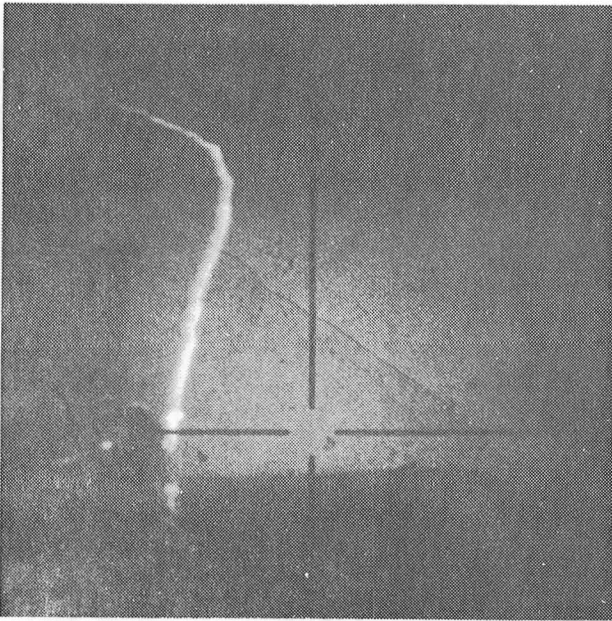
Figure 101. - Continued.



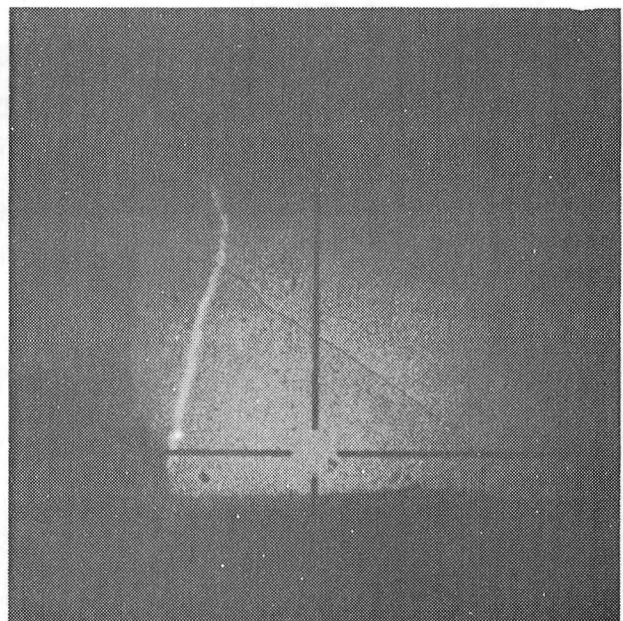
(i) Frame 9 of 13.



(j) Frame 10 of 13.

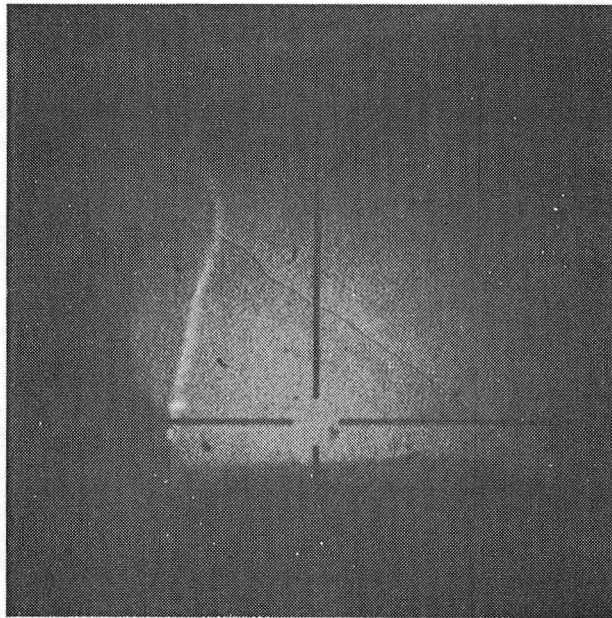


(k) Frame 11 of 13.



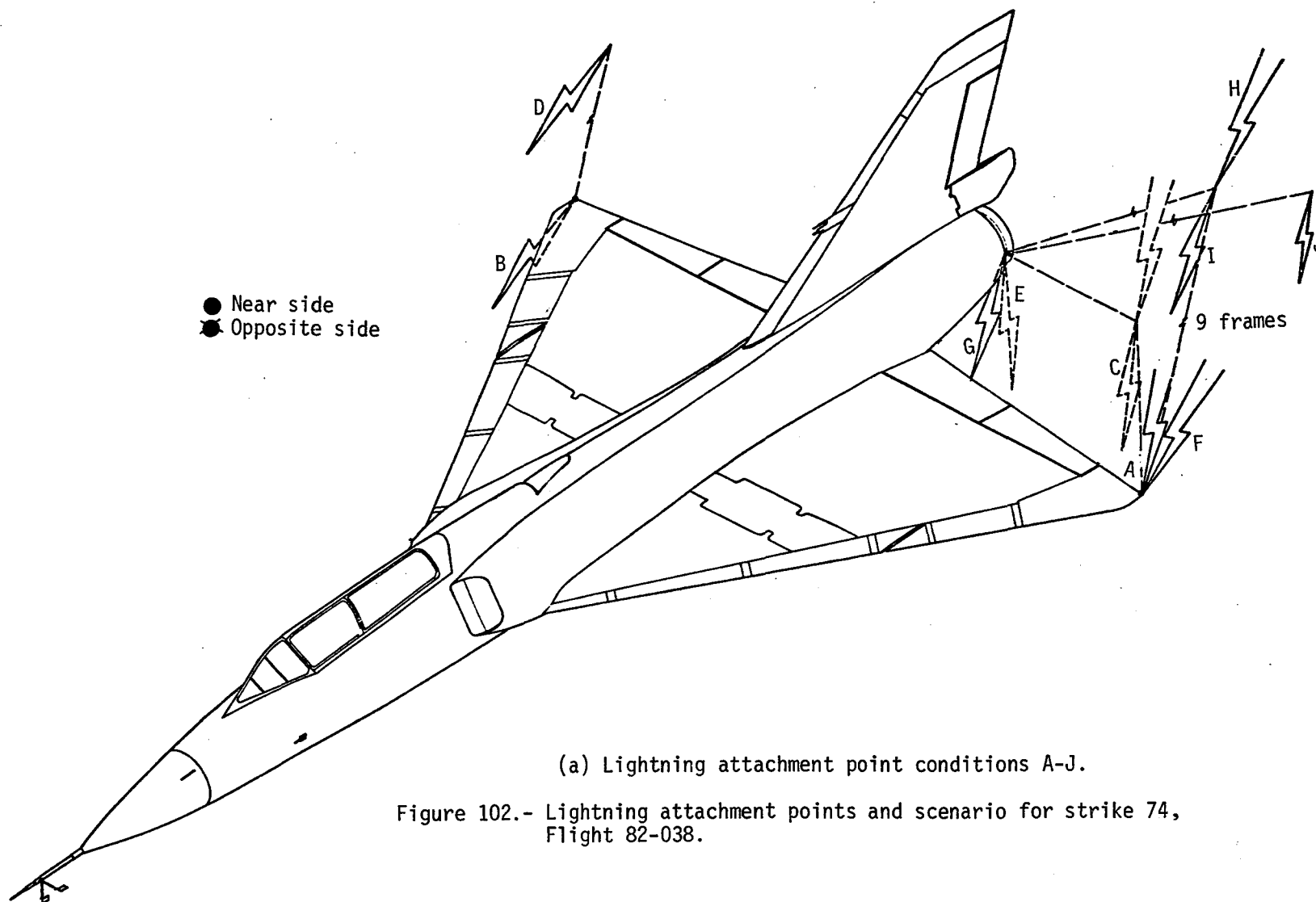
(l) Frame 12 of 13.

Figure 101. - Continued.



(m) Frame 13 of 13.

Figure 101. - Concluded.



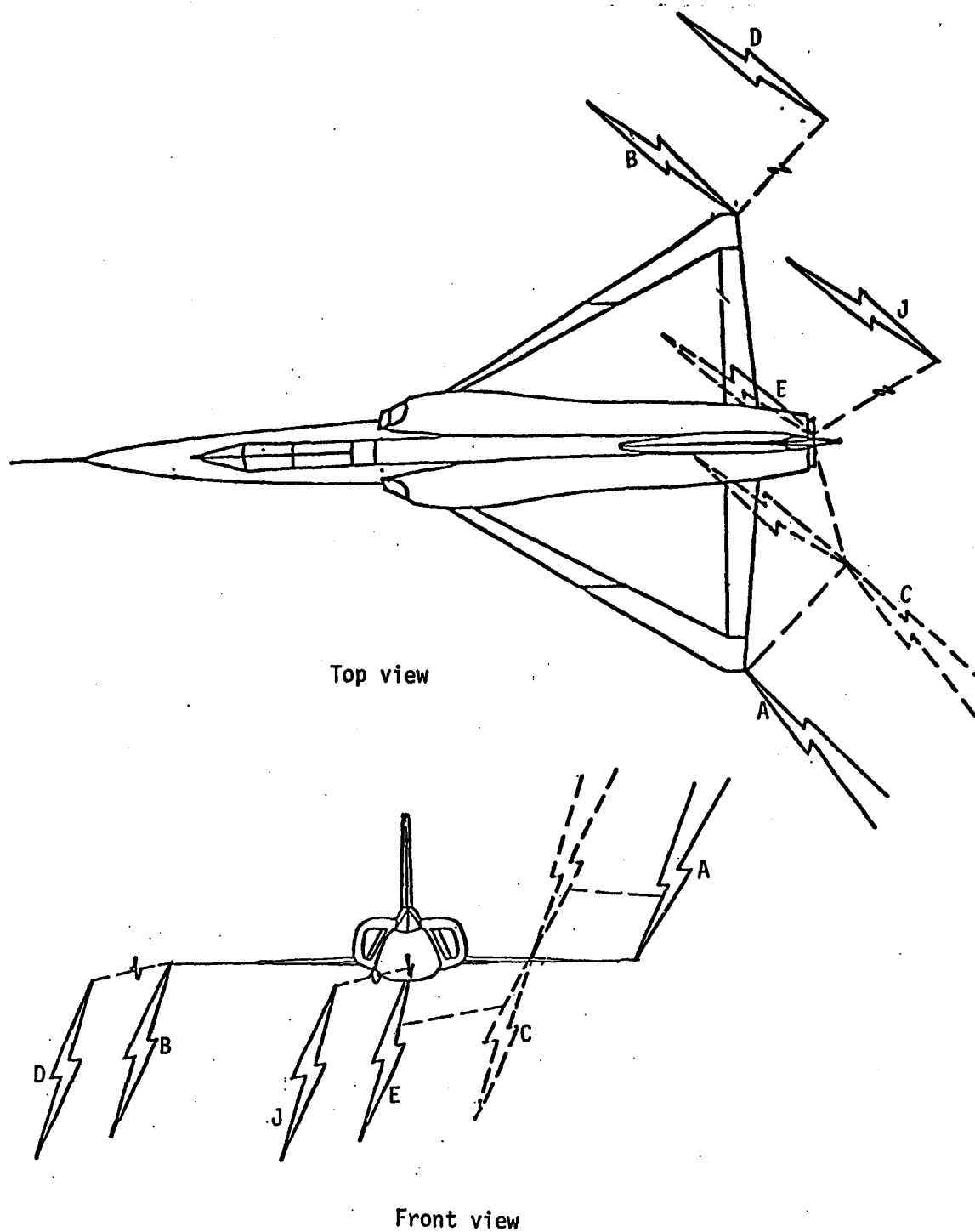
(a) Lightning attachment point conditions A-J.

Figure 102.- Lightning attachment points and scenario for strike 74, Flight 82-038.

- A Initial entry for branch 1 at left wingtip
- B Initial exit for branch 1 at right wingtip
- C Entry for branch 1 detaches from wingtip and continues downward
- D Final exit for branch 1 (dies out)
- E Entry for branch 1 reattaches to tailpipe and continues downward
- F New initial entry, branch 2, at left wingtip
- G Initial exit for branch 2 at tailpipe
- H Entry and exit for branch 2 combine aft of airplane
- I Exit for branch 2 dies out
- J Entry for branch 1 dies out

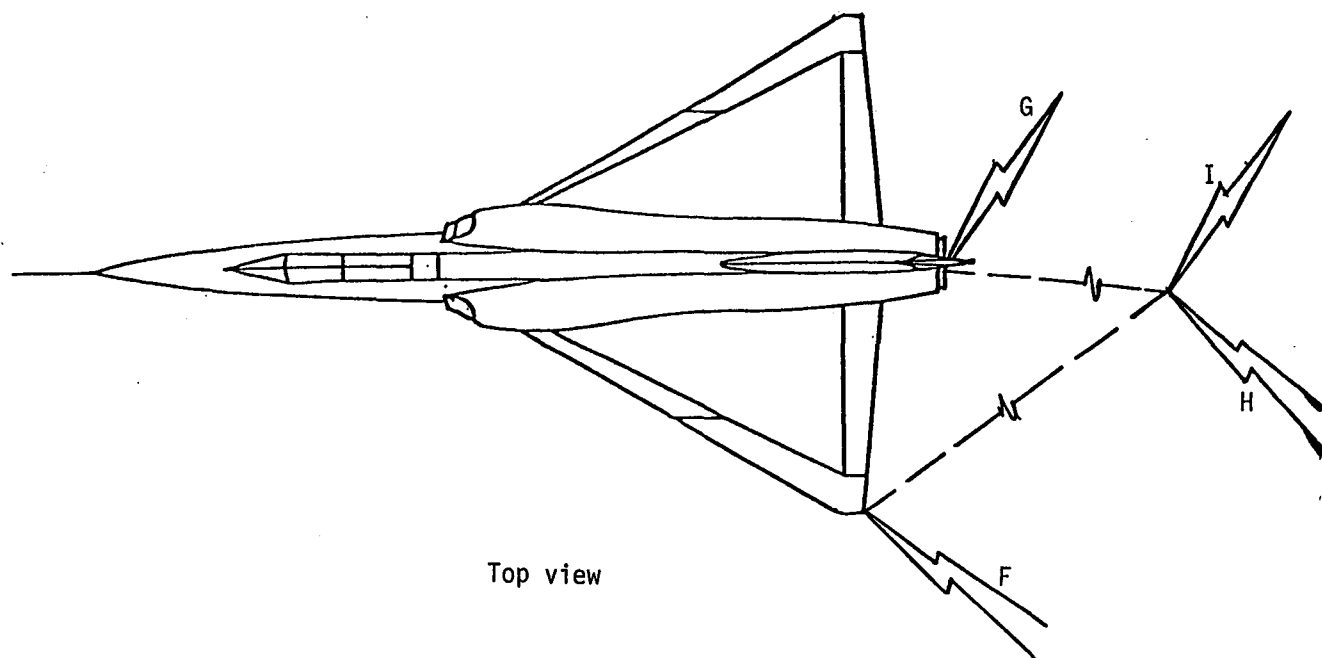
(b) Key to Figures 102 and 103.

Figure 102.- Concluded.

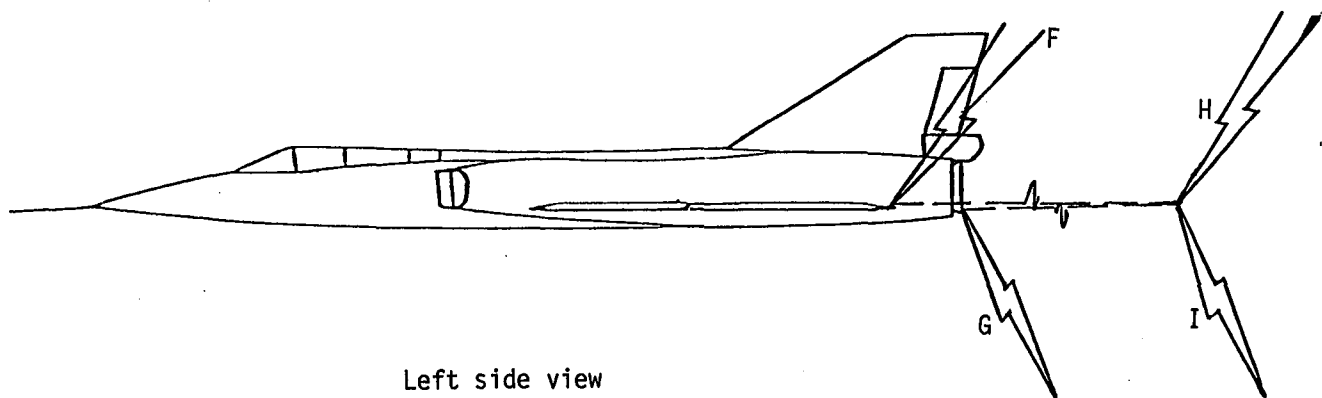


(a) Lightning attachment conditions A, B, C, D, E, and J.

Figure 103.- Lightning attachment point scenario for strike 74, Flight 82-038.



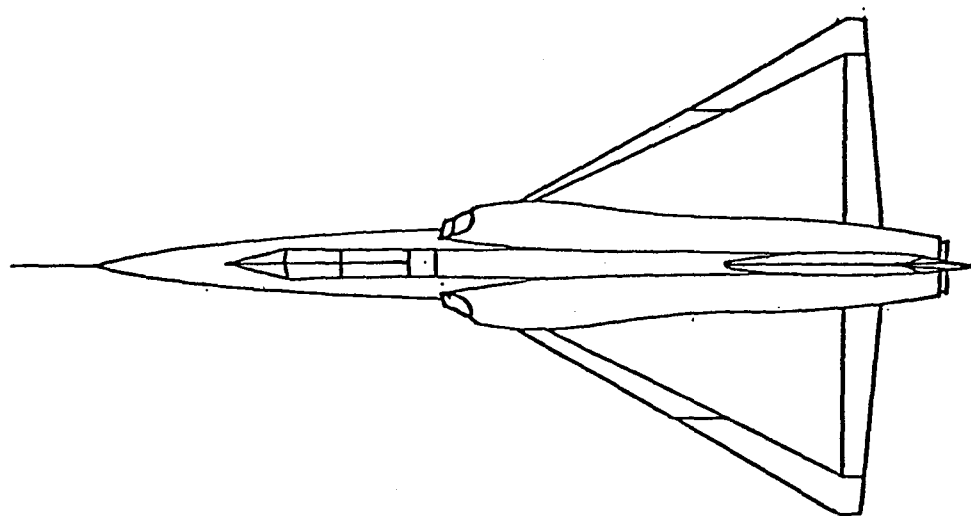
Top view



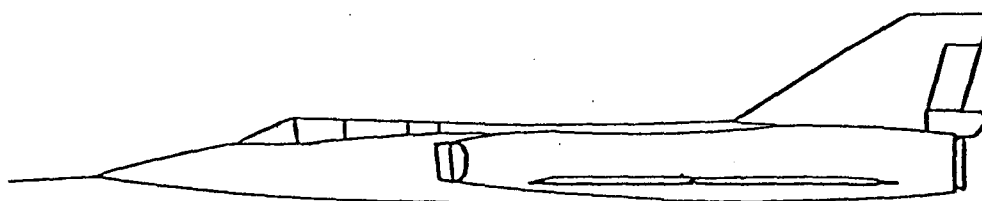
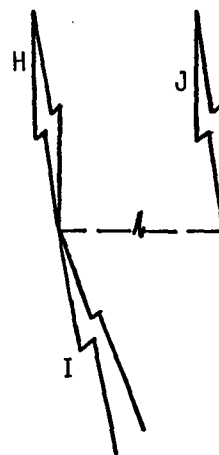
Left side view

(b) Lightning attachment conditions F, G, H, and I.

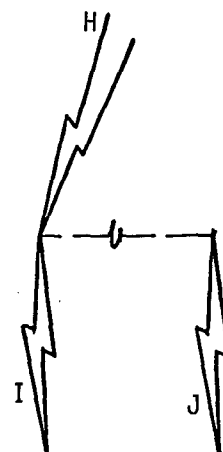
Figure 103.- Continued.



Top view

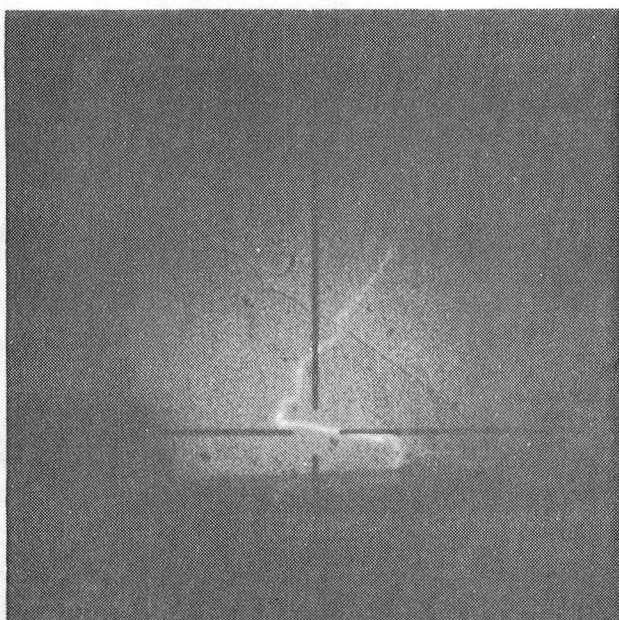


Left side view

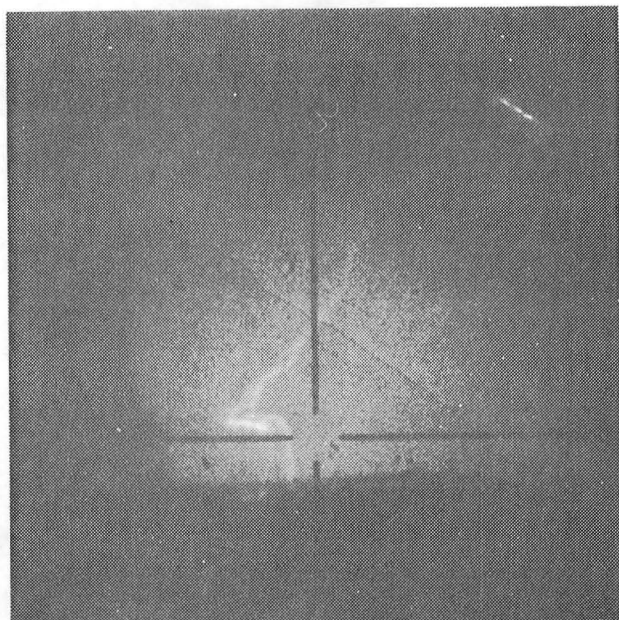


(c) Lightning attachment point conditions H, I, and J.

Figure 103.- Concluded.



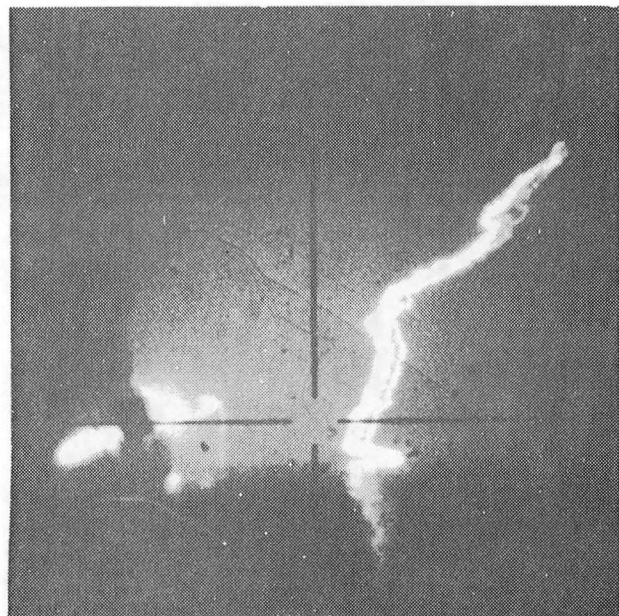
(a) Frame 1 of 9.



(b) Frame 2 of 9.



(c) Frame 3 of 9.

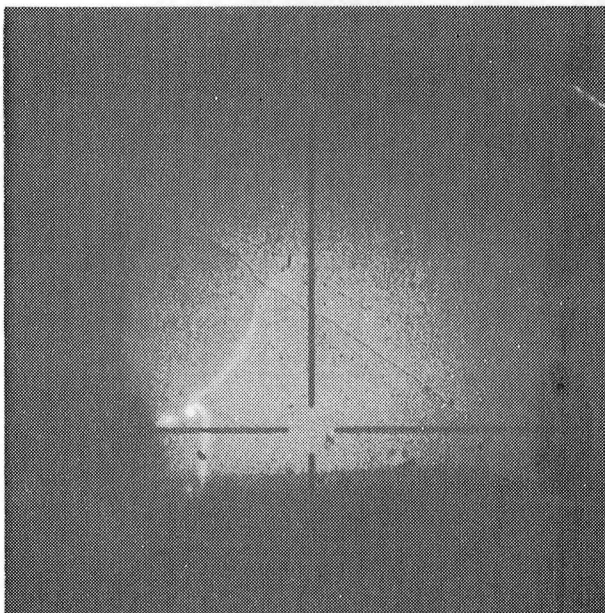


(d) Frame 4 of 9.

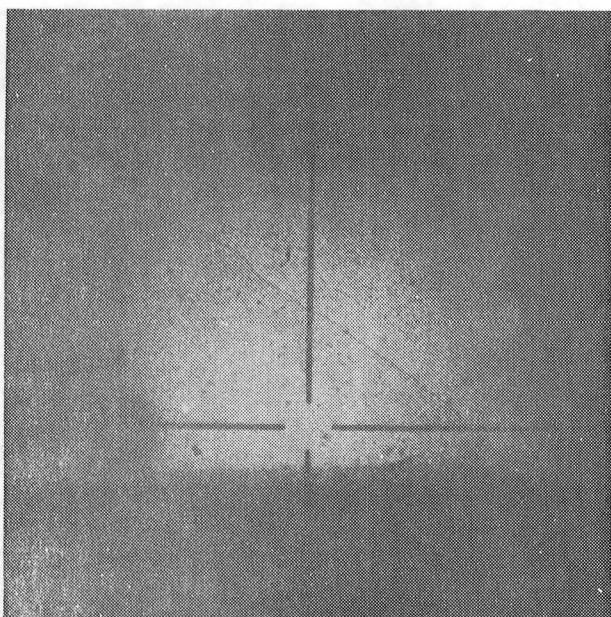
Figure 104. - Strike 74, Flight 82-038, aft camera.



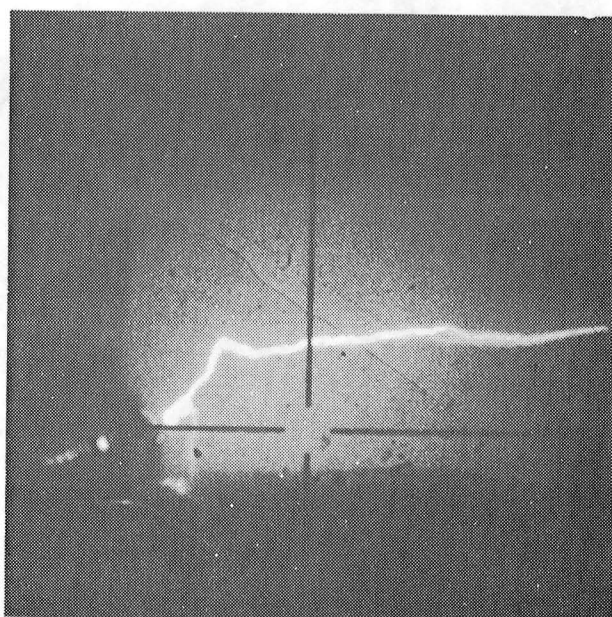
(e) Frame 5 of 9.



(f) Frame 6 of 9.

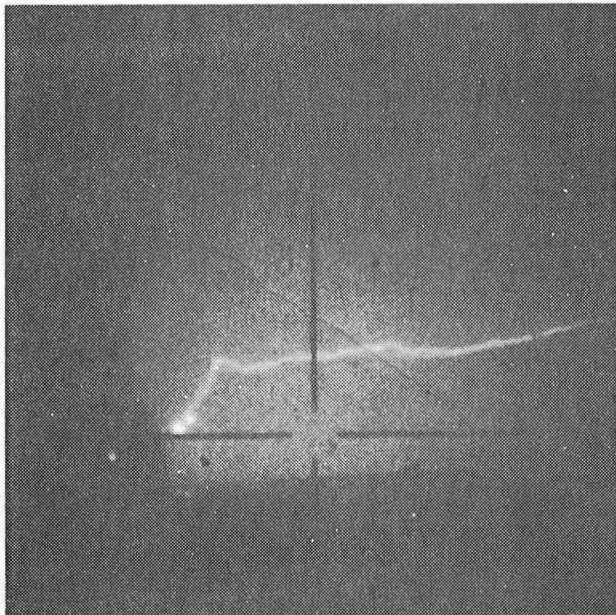


(g) Frame 7 of 9.



(h) Frame 8 of 9.

Figure 104. - Continued.



(i) Frame 9 of 9.

Figure 104. - Concluded.

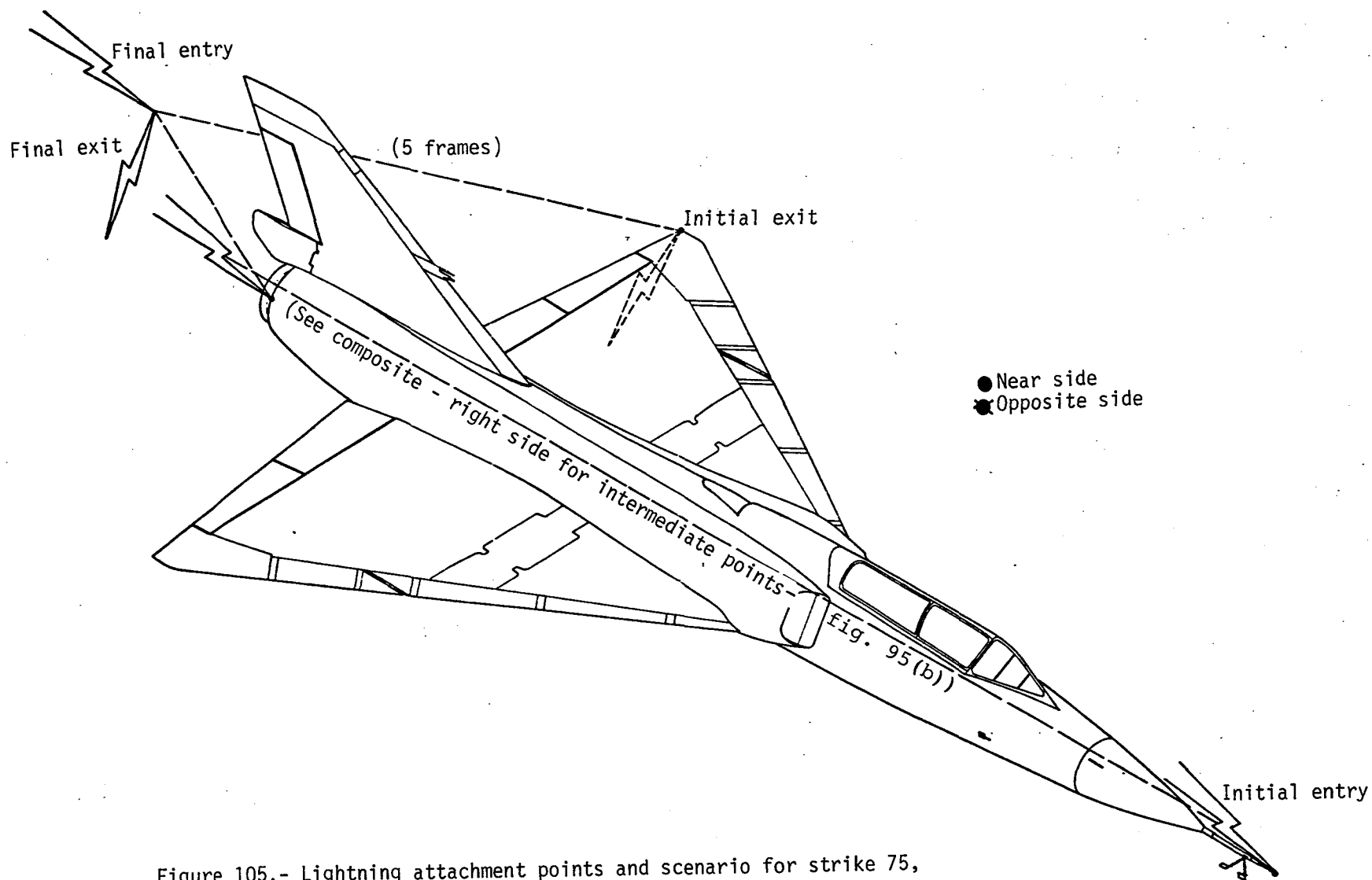


Figure 105.- Lightning attachment points and scenario for strike 75, Flight 82-038.

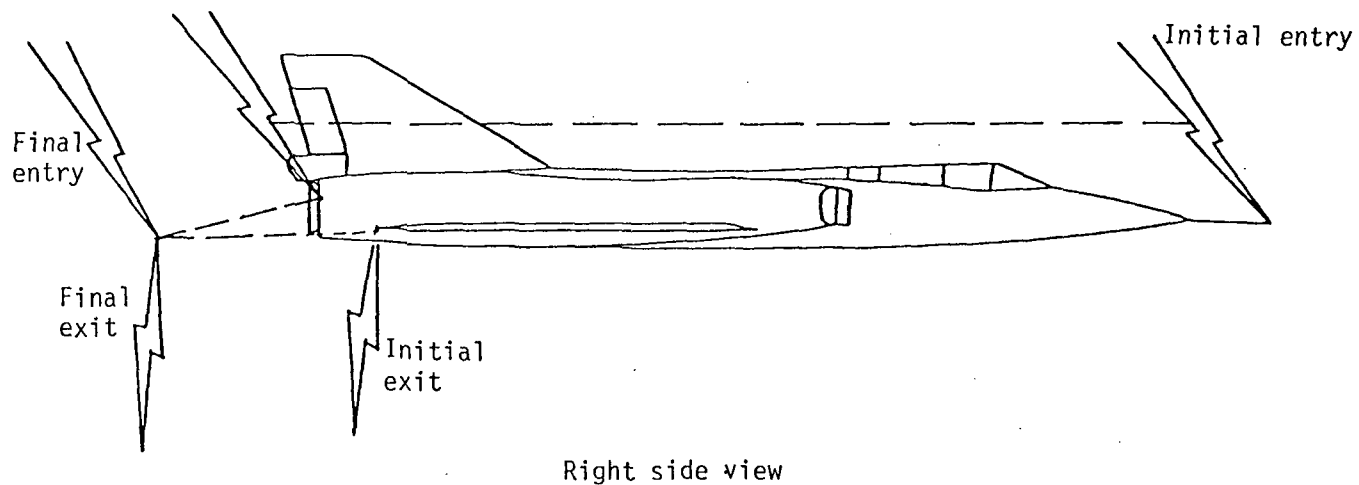
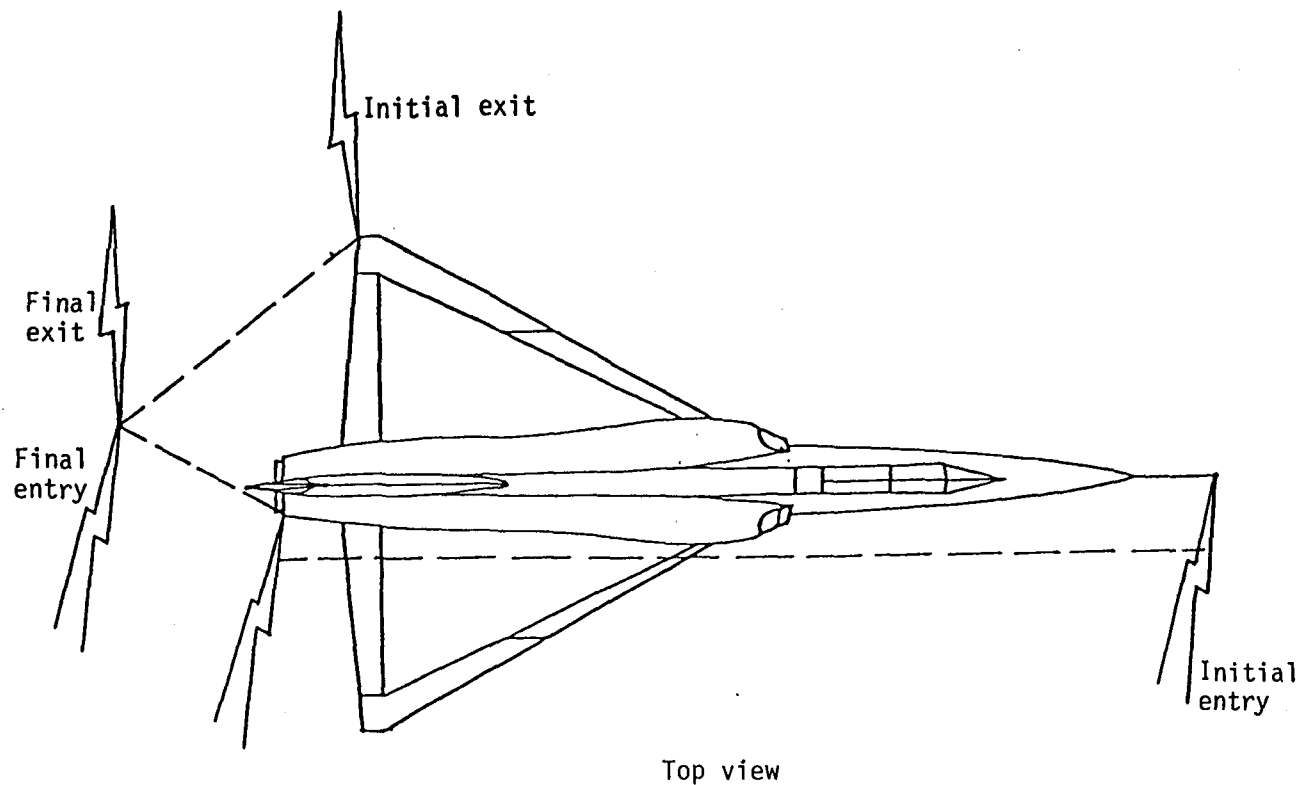
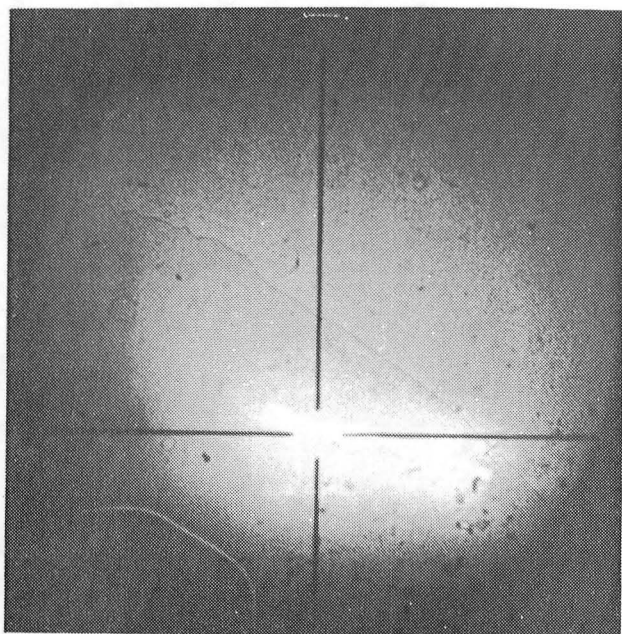
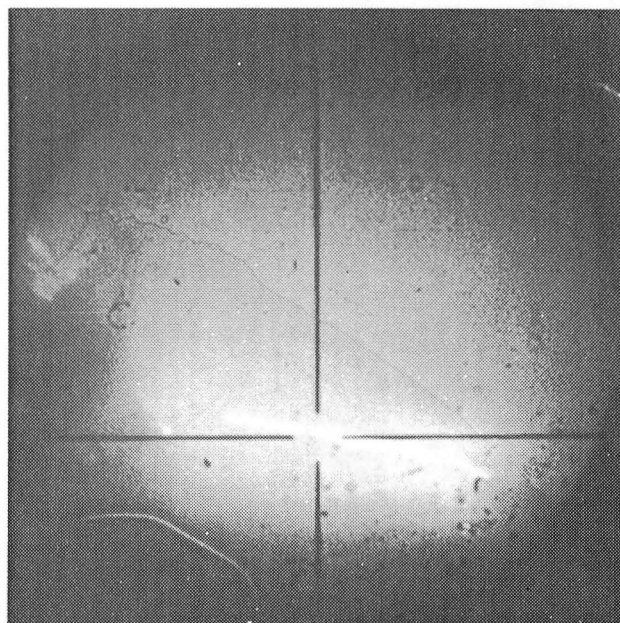


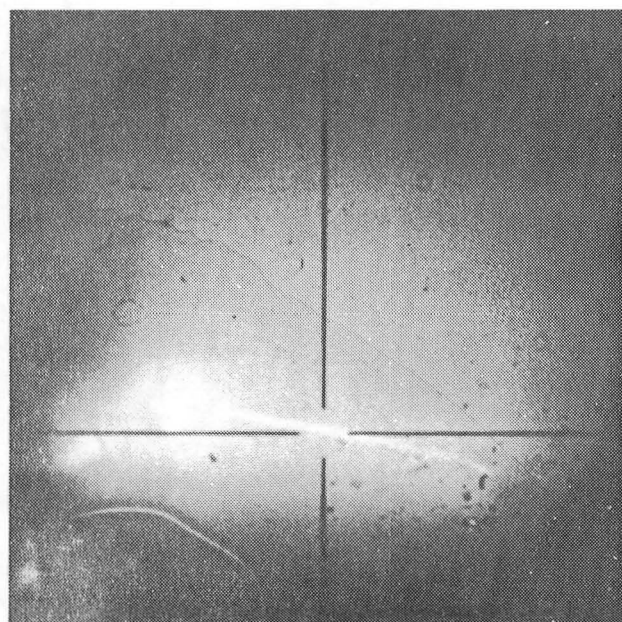
Figure 106.- Lightning attachment point scenario for strike 75, Flight 82-038.



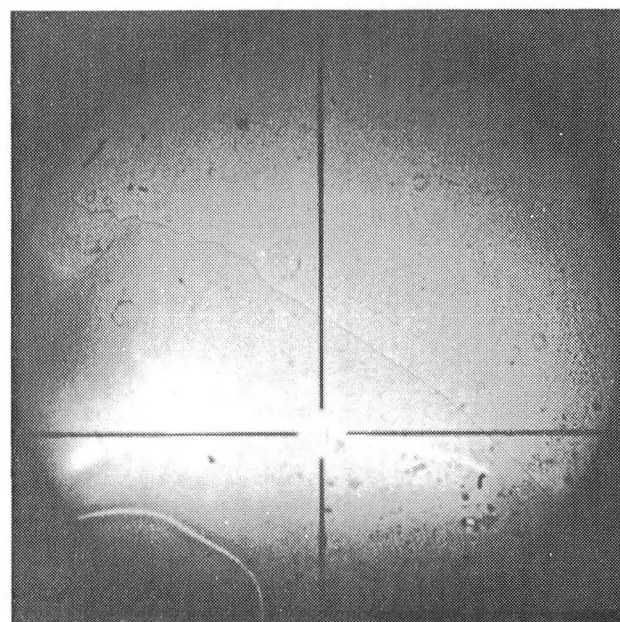
(a) Frame 1 of 5.



(b) Frame 2 of 5.

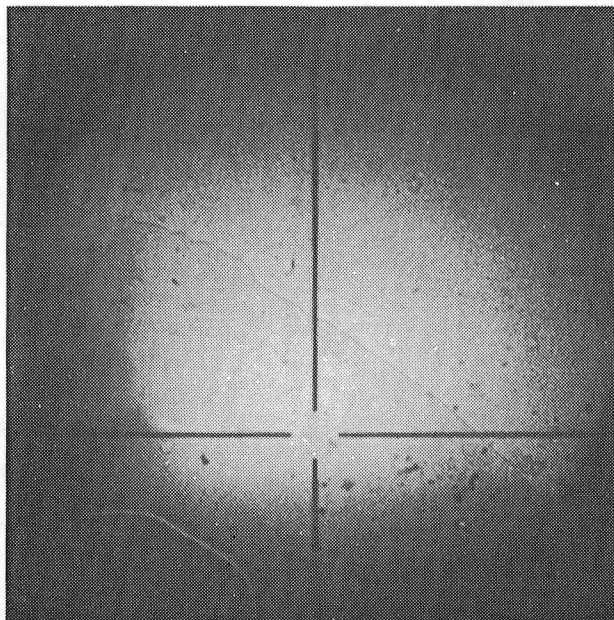


(c) Frame 3 of 5.



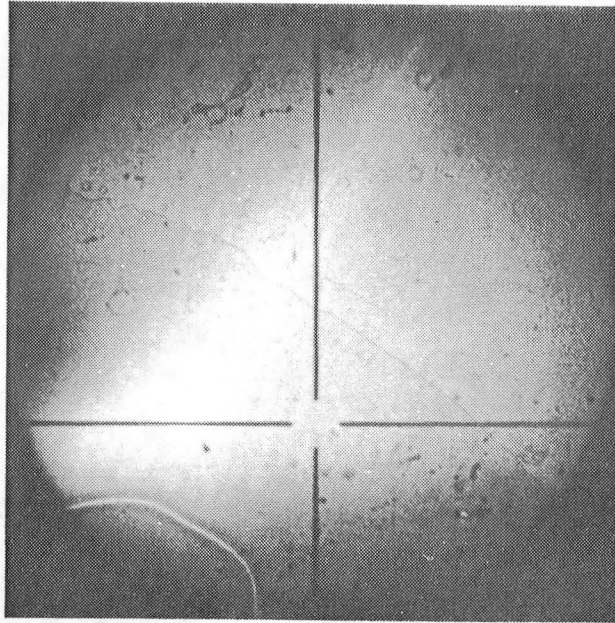
(d) Frame 4 of 5.

Figure 107. - Strike 75, Flight 82-038, aft camera.

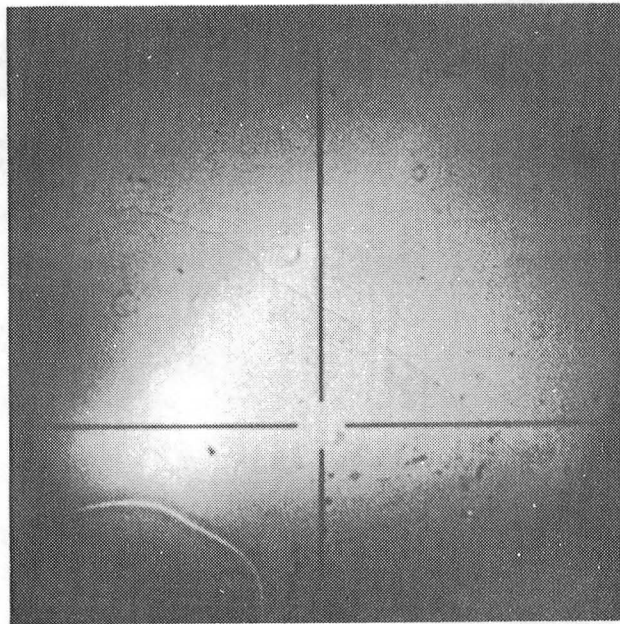


(e) Frame 5 of 5.

Figure 107. - Concluded.

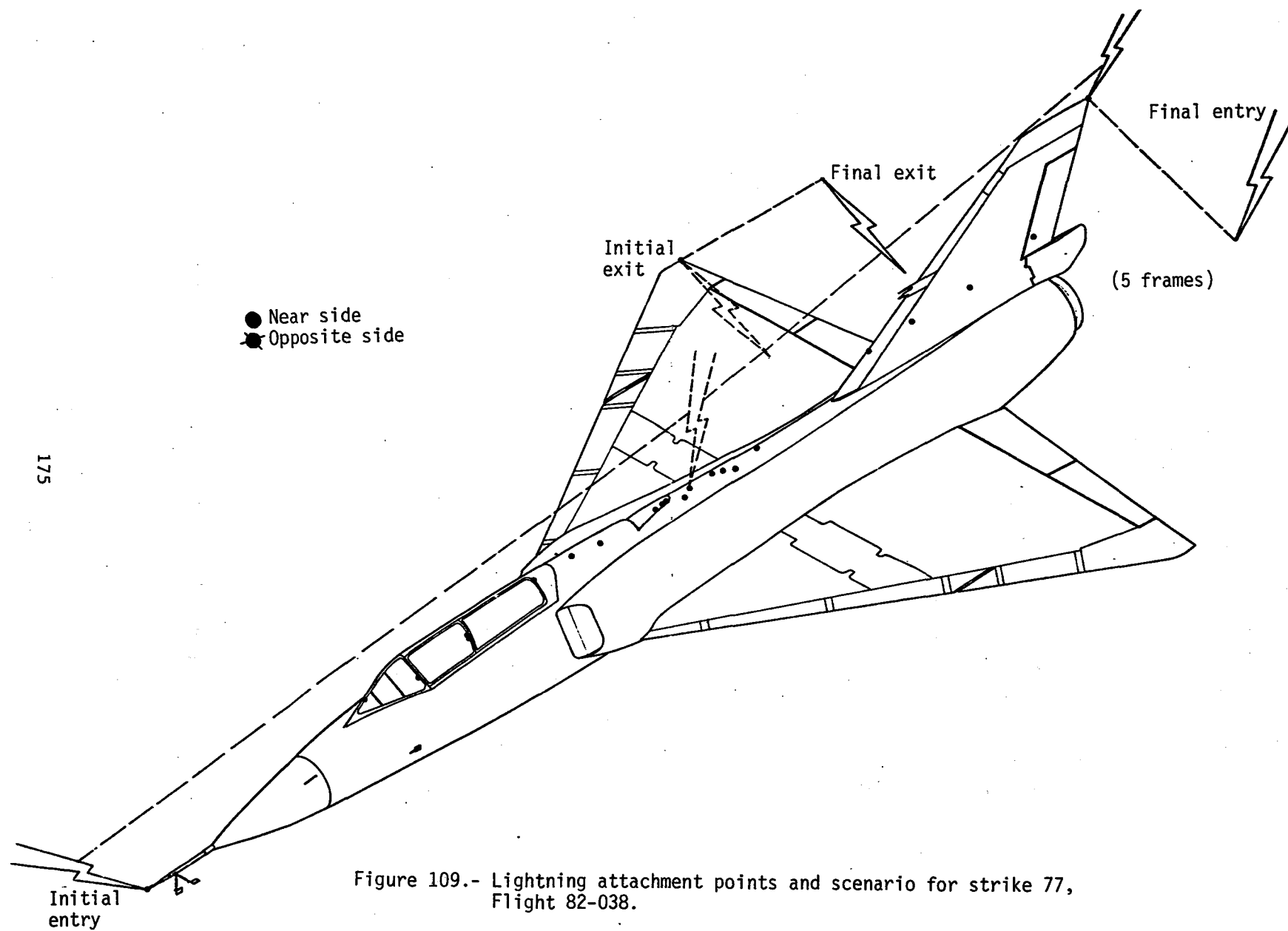


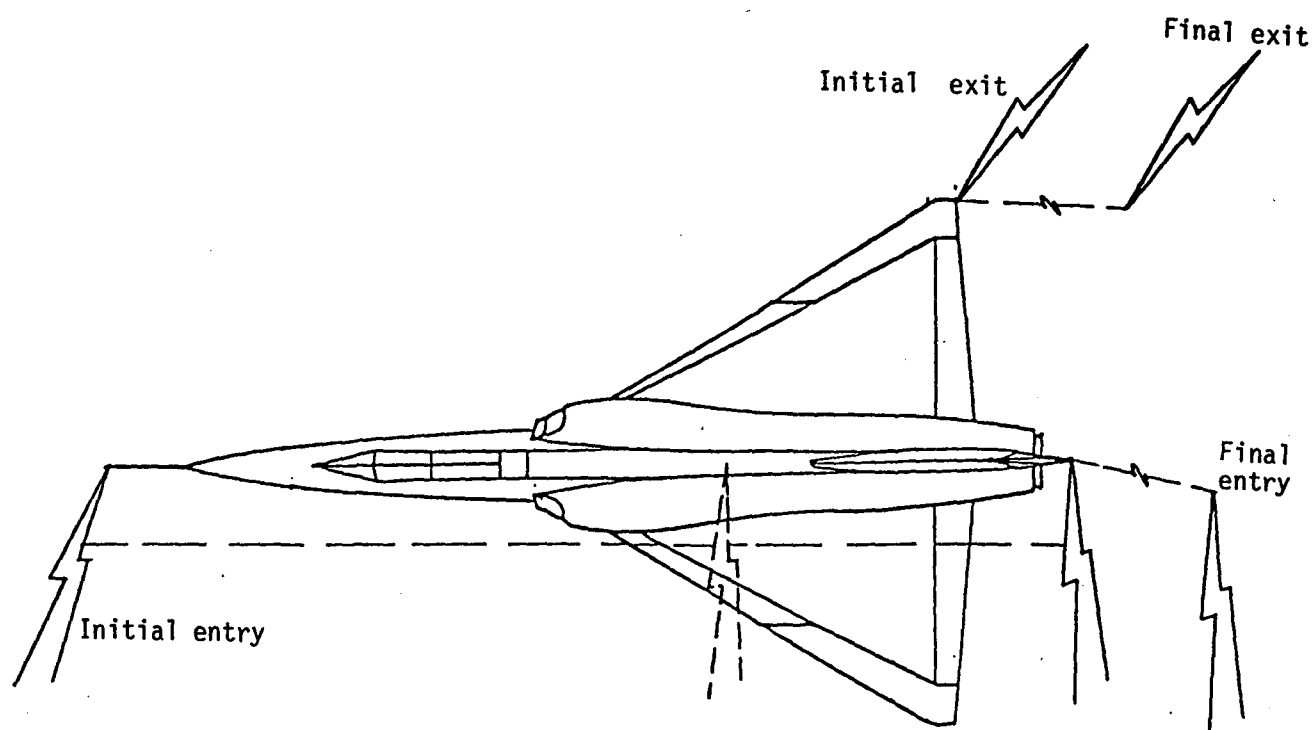
(a) Frame 1 of 2.



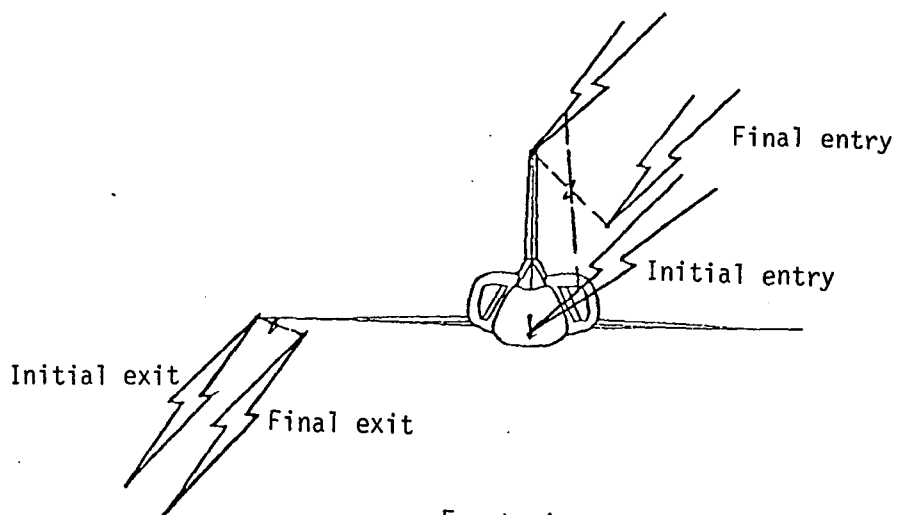
(b) Frame 2 of 2.

Figure 108. - Strike 76, Flight 82-038, aft camera.



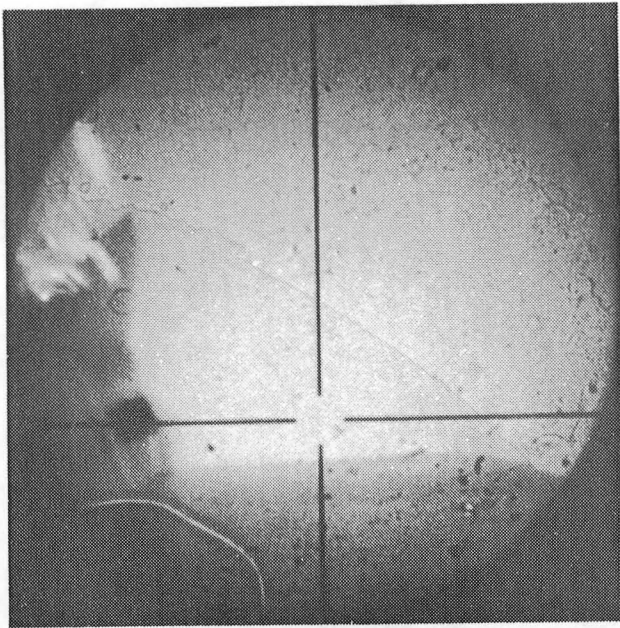


Top view

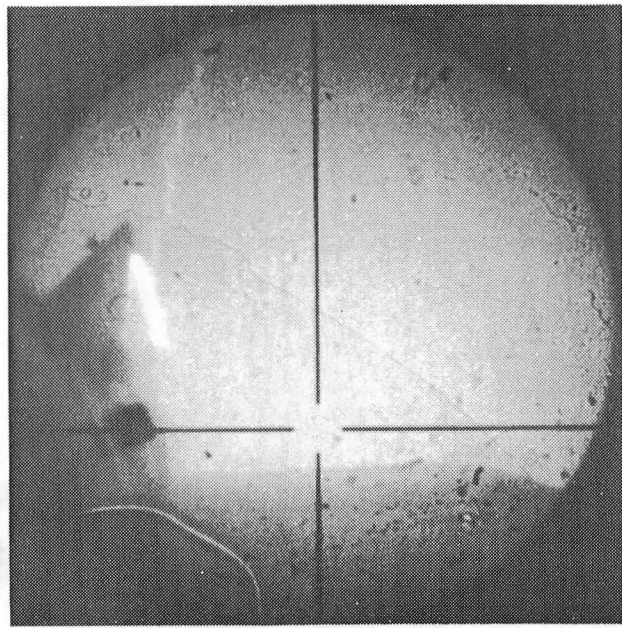


Front view

Figure 110.- Lightning attachment point scenario for strike 77, Flight 82-038.



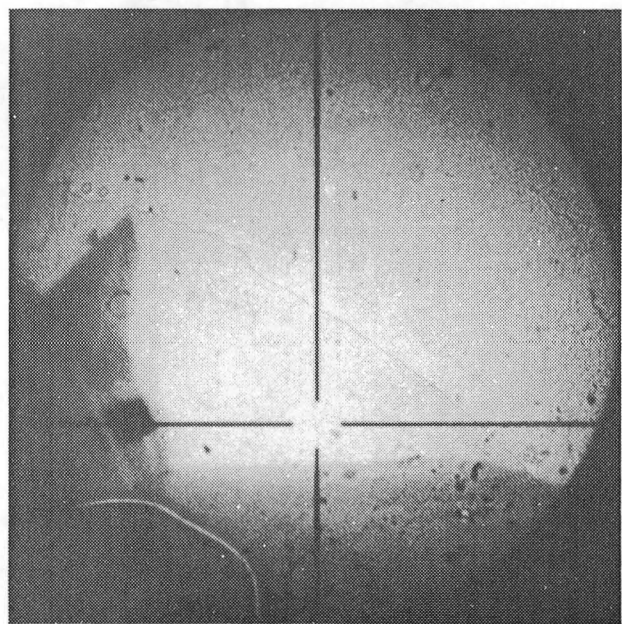
(a) Frame 1 of 5.



(b) Frame 2 of 5.

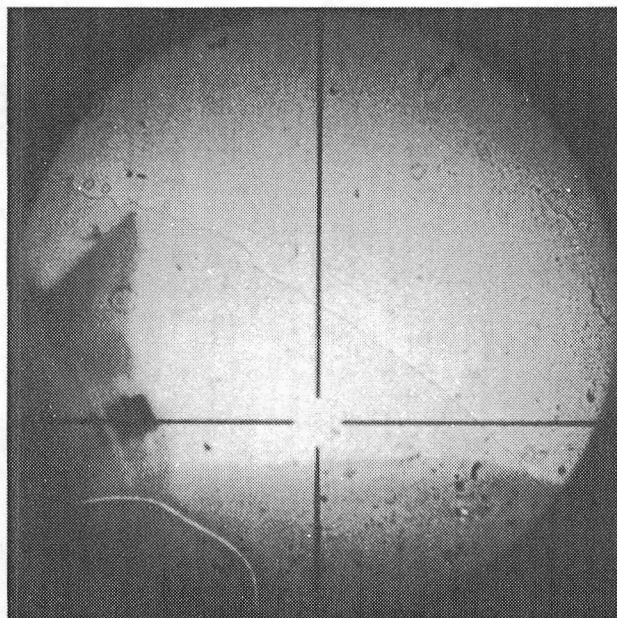


(c) Frame 3 of 5.



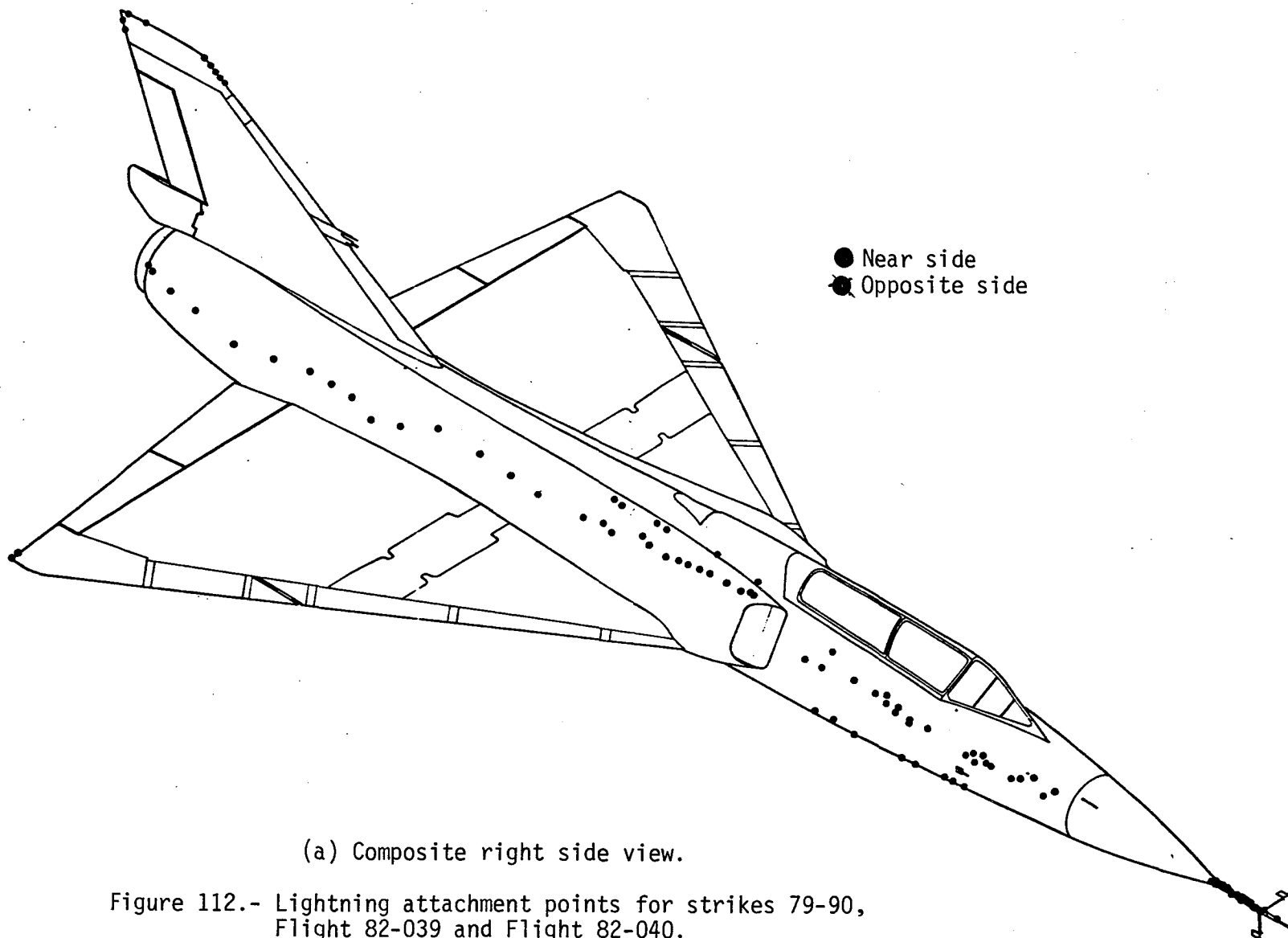
(d) Frame 4 of 5.

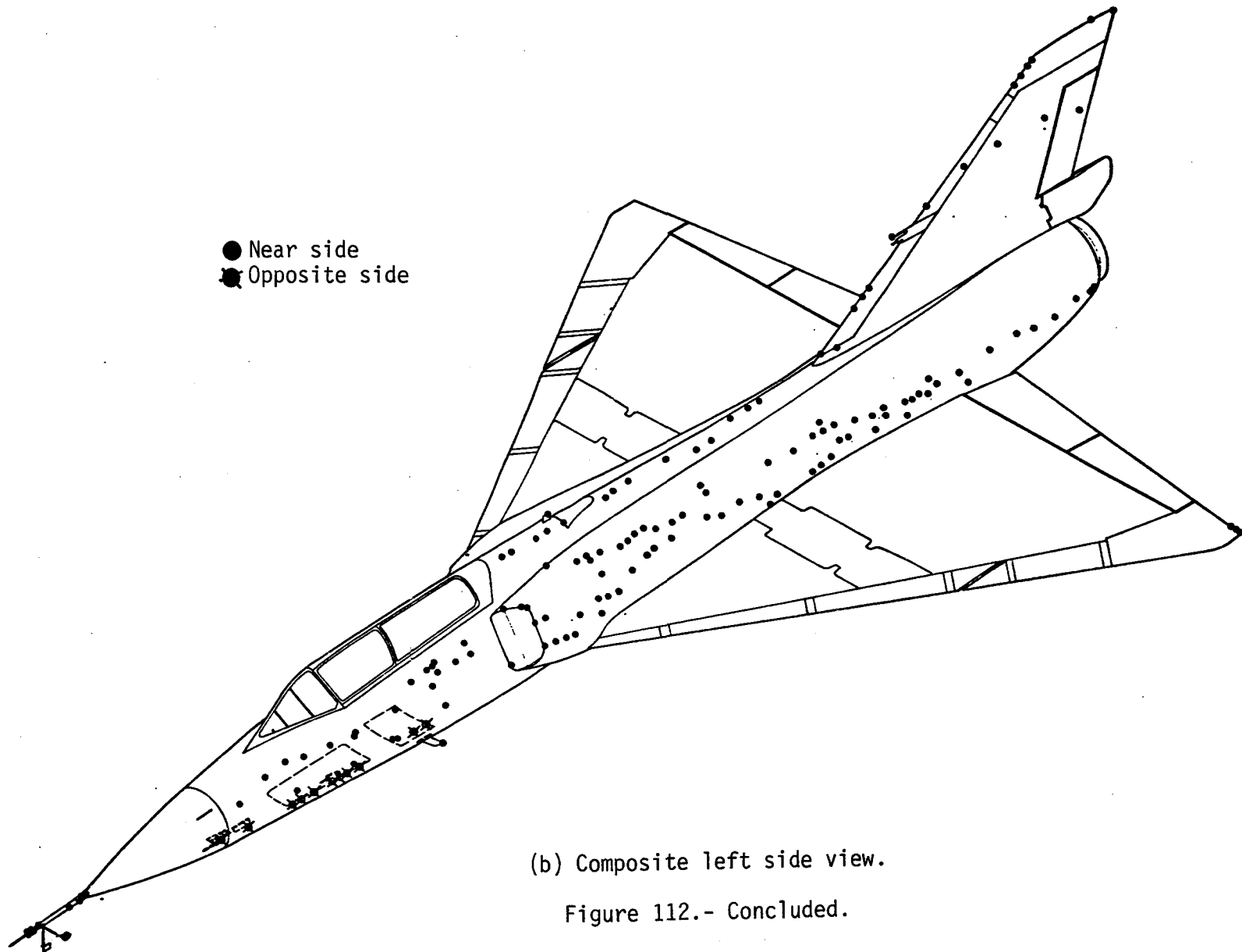
Figure 111. - Strike 77, Flight 82-038, aft camera.



(e) Frame 5 of 5.

Figure 111. - Concluded.





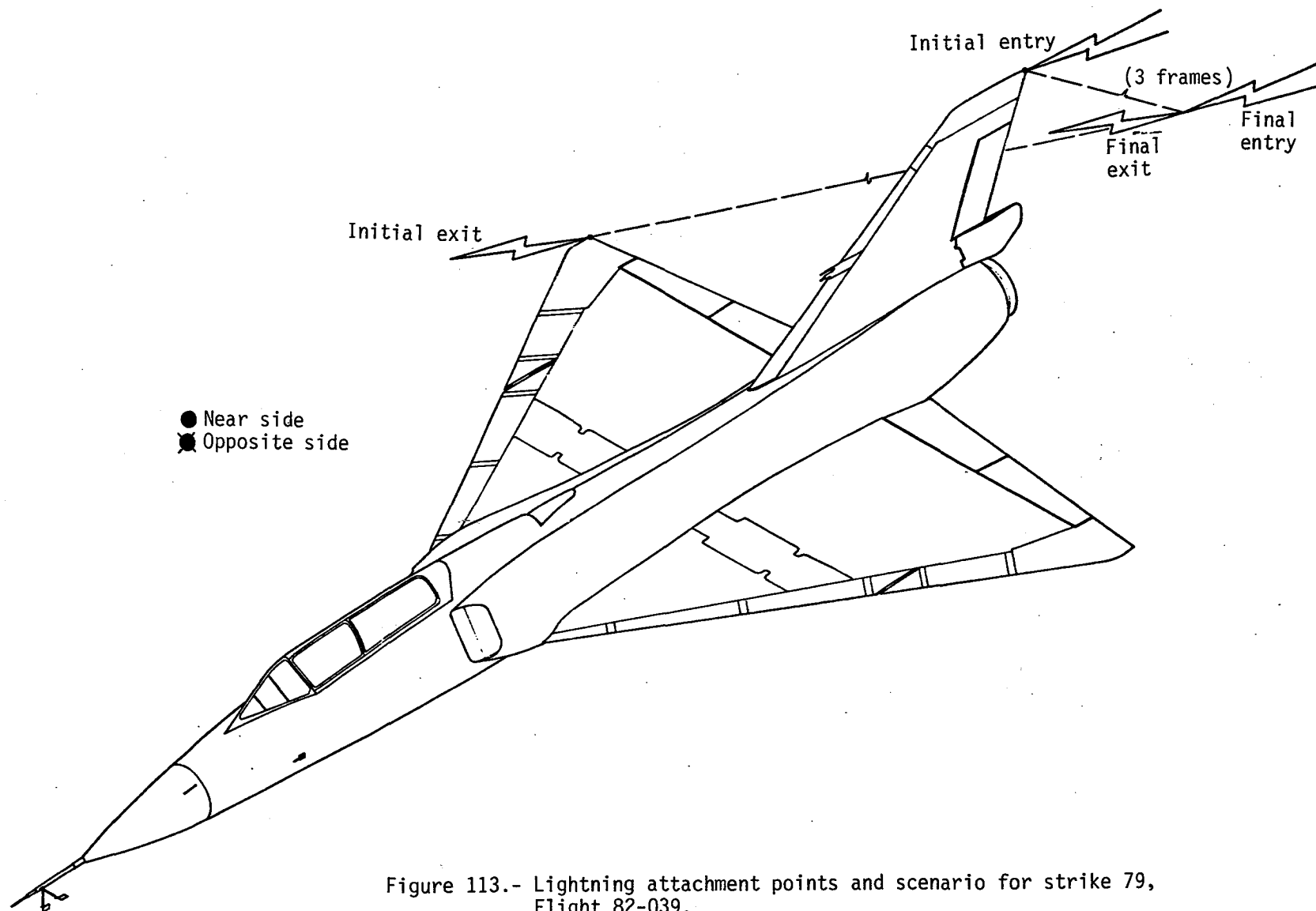


Figure 113.- Lightning attachment points and scenario for strike 79, Flight 82-039.

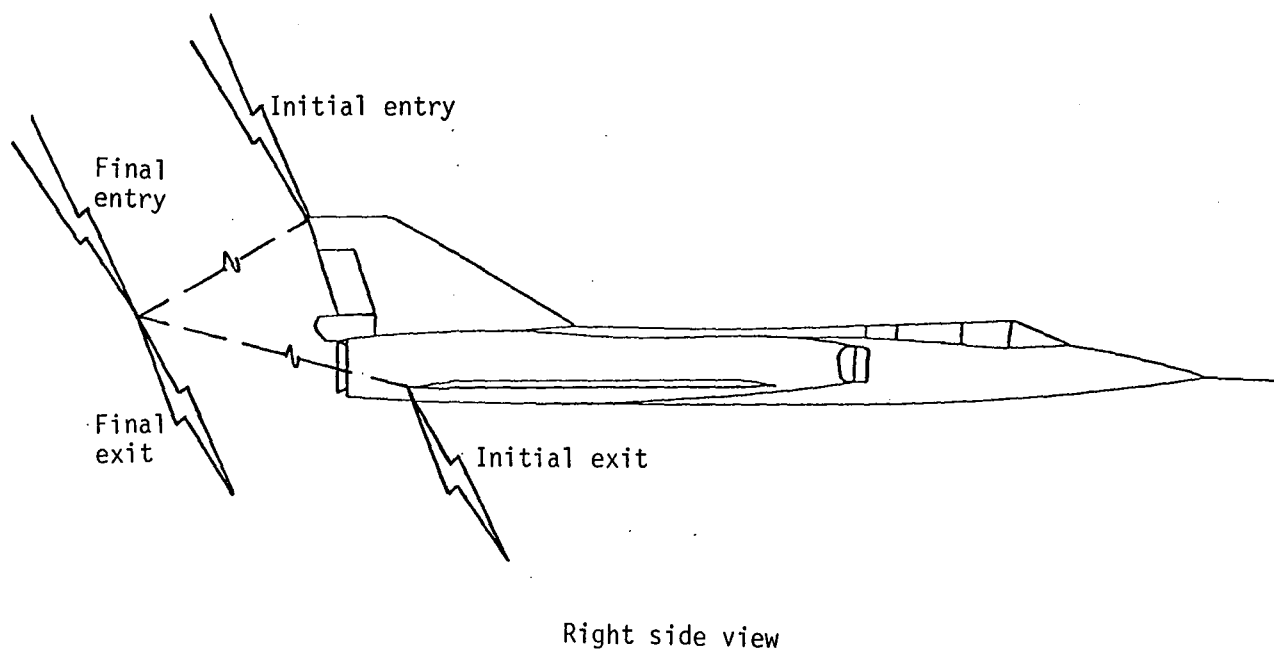
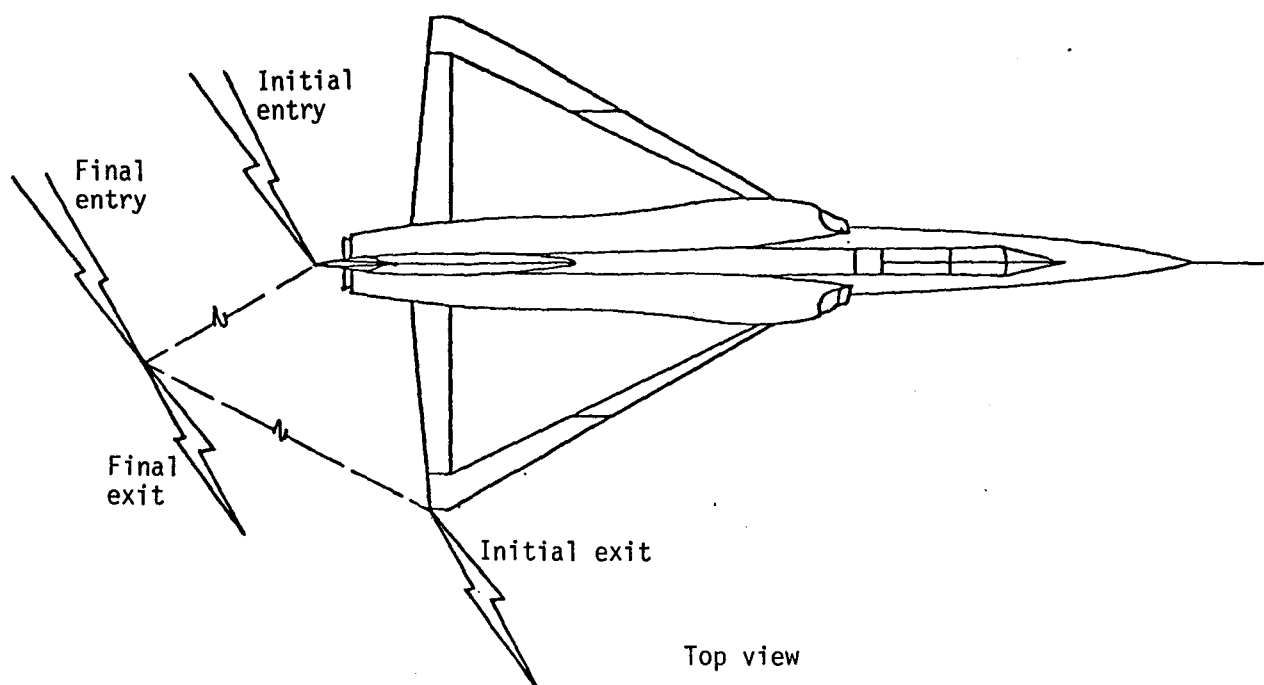
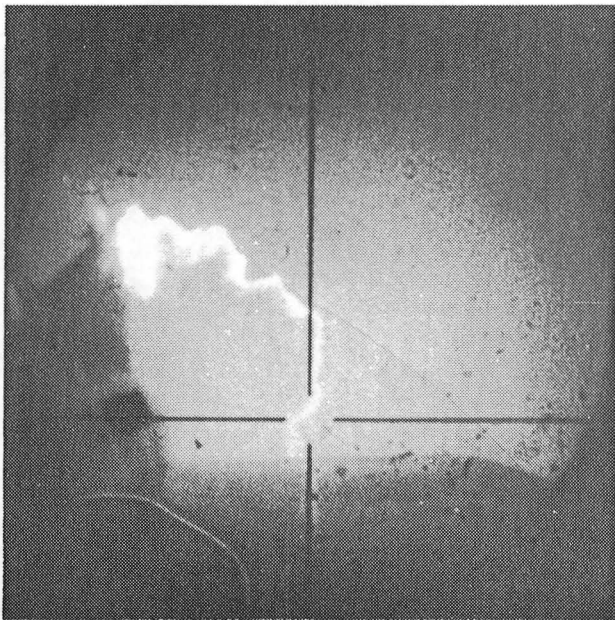
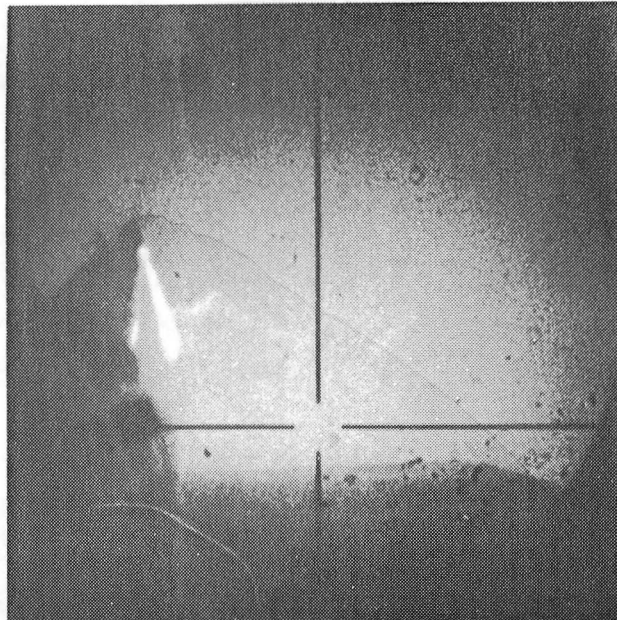


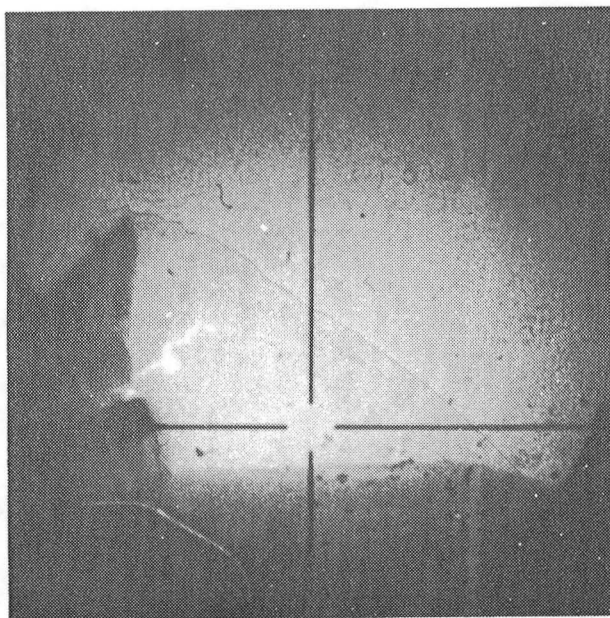
Figure 114.- Lightning attachment point scenario for strike 79, Flight 82-039.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 115. - Strike 79, Flight 82-039, aft camera.

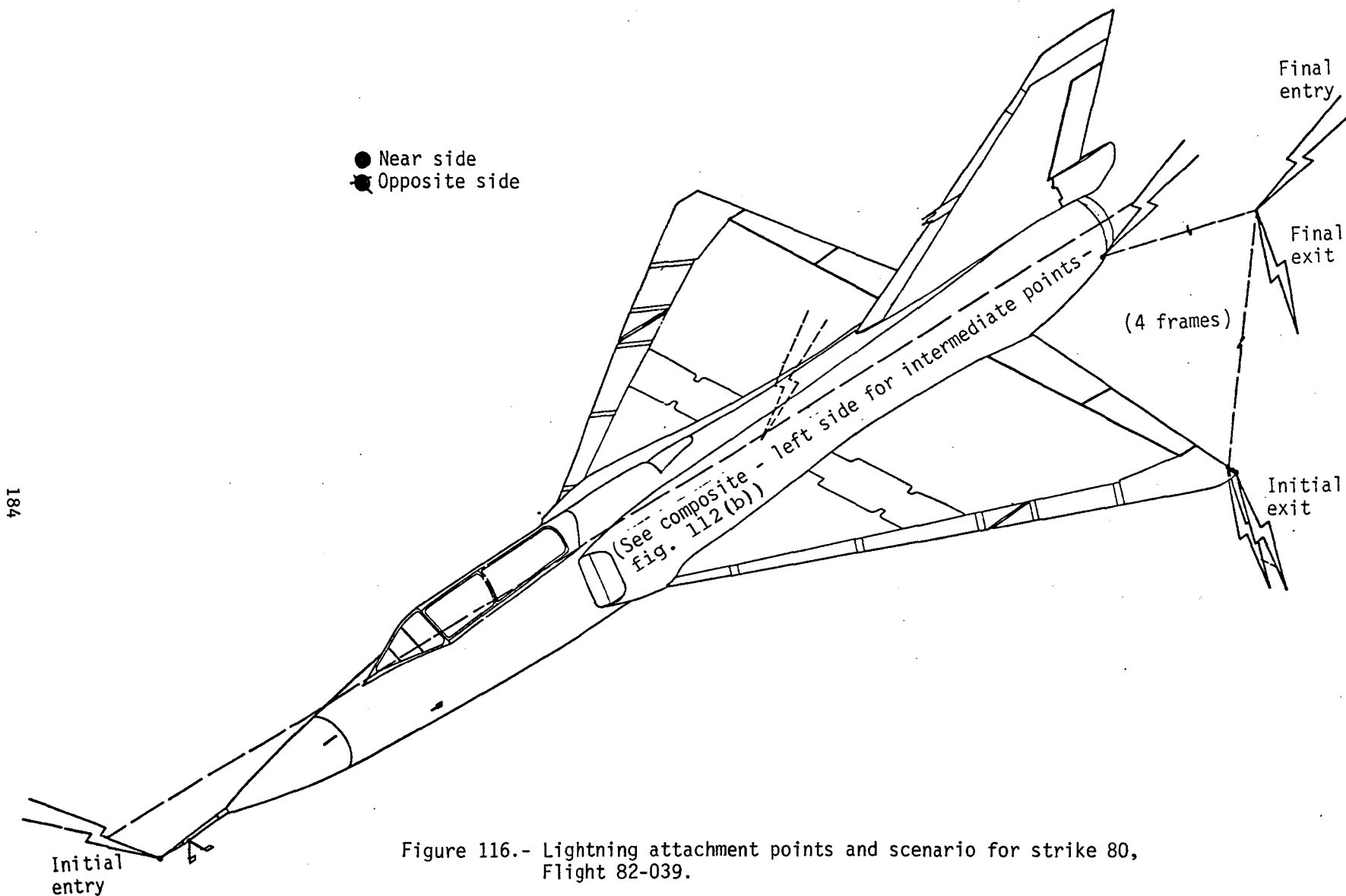


Figure 116.- Lightning attachment points and scenario for strike 80,
Flight 82-039.

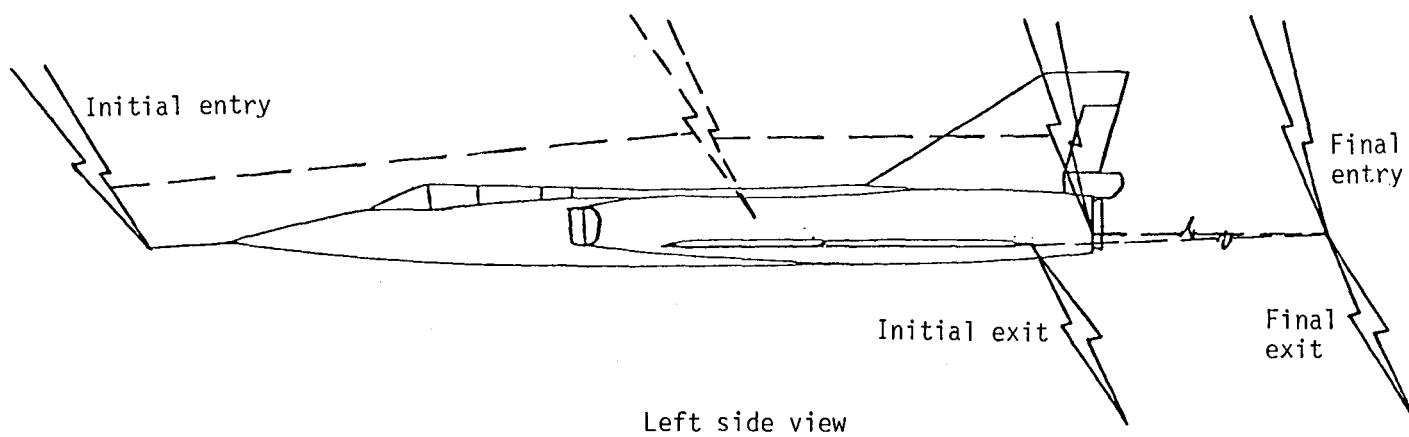
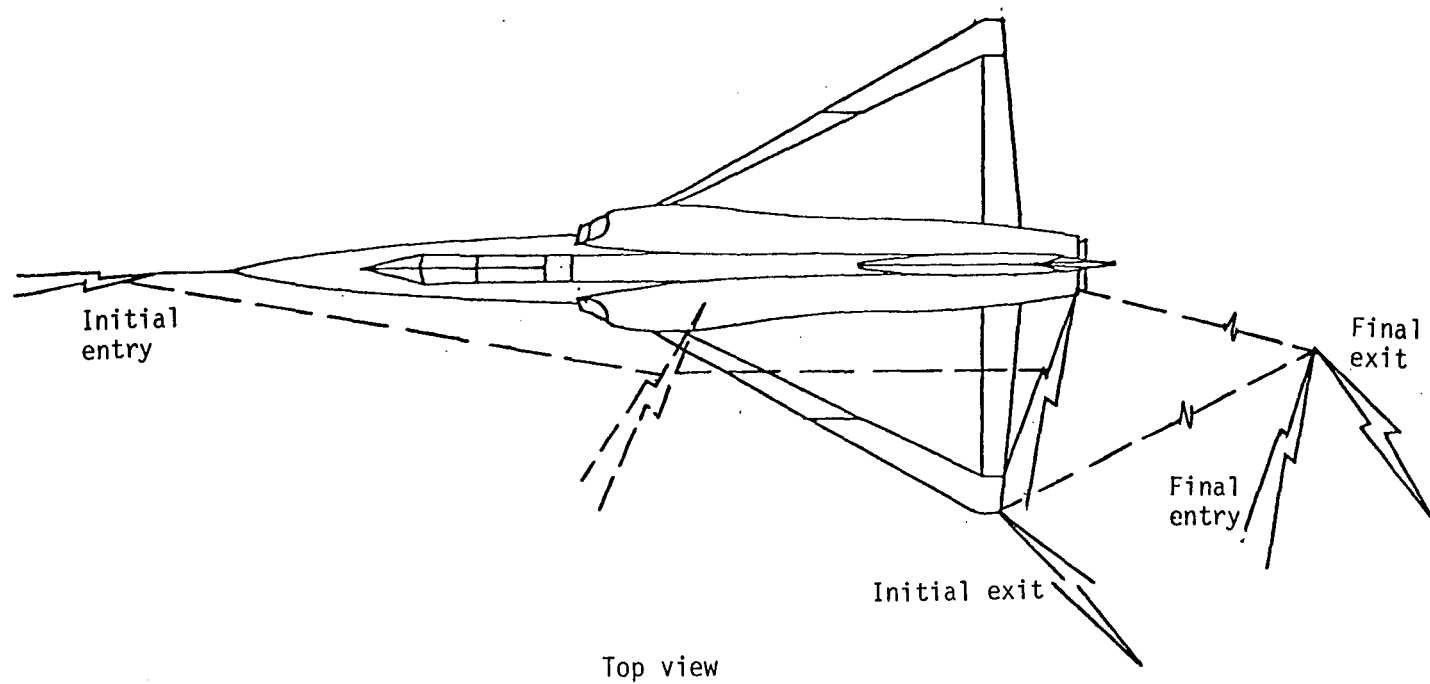
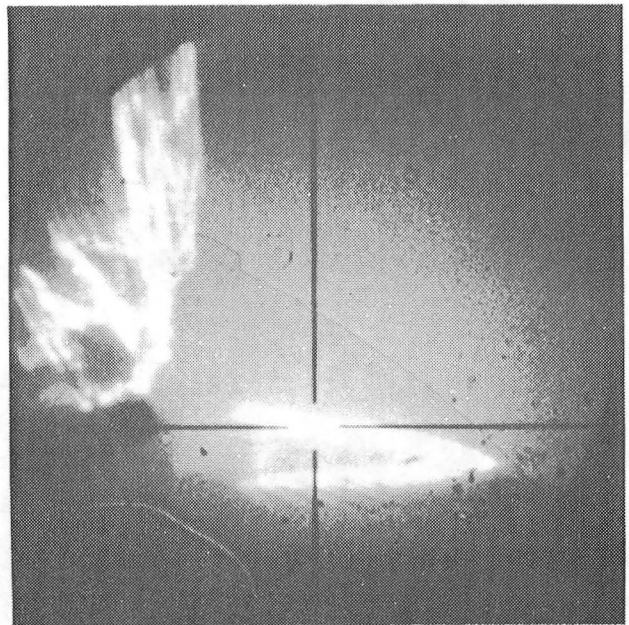


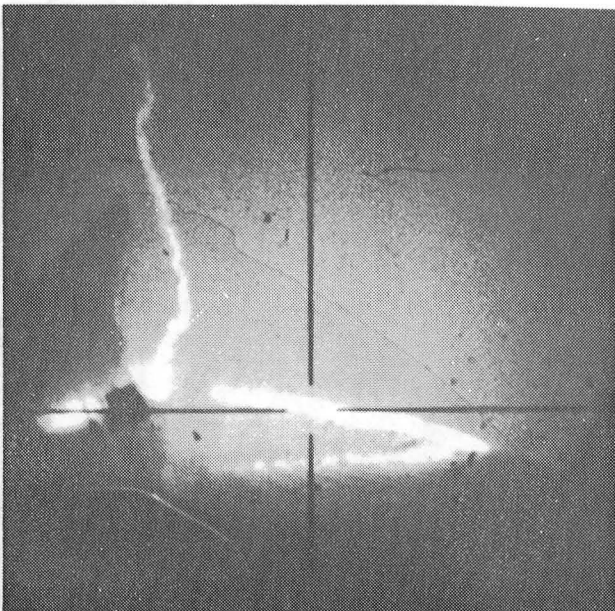
Figure 117.- Lightning attachment point scenario for strike 80, Flight 82-039.



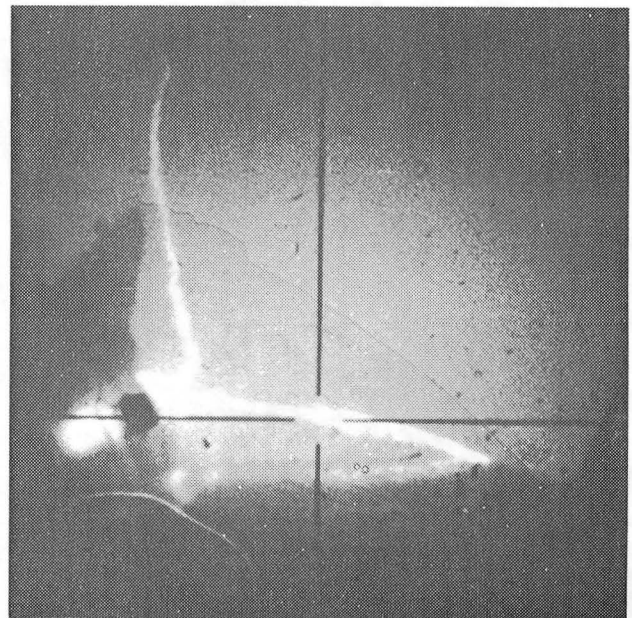
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.



(d) Frame 4 of 4.

Figure 118. - Strike 80, Flight 82-039, aft camera.

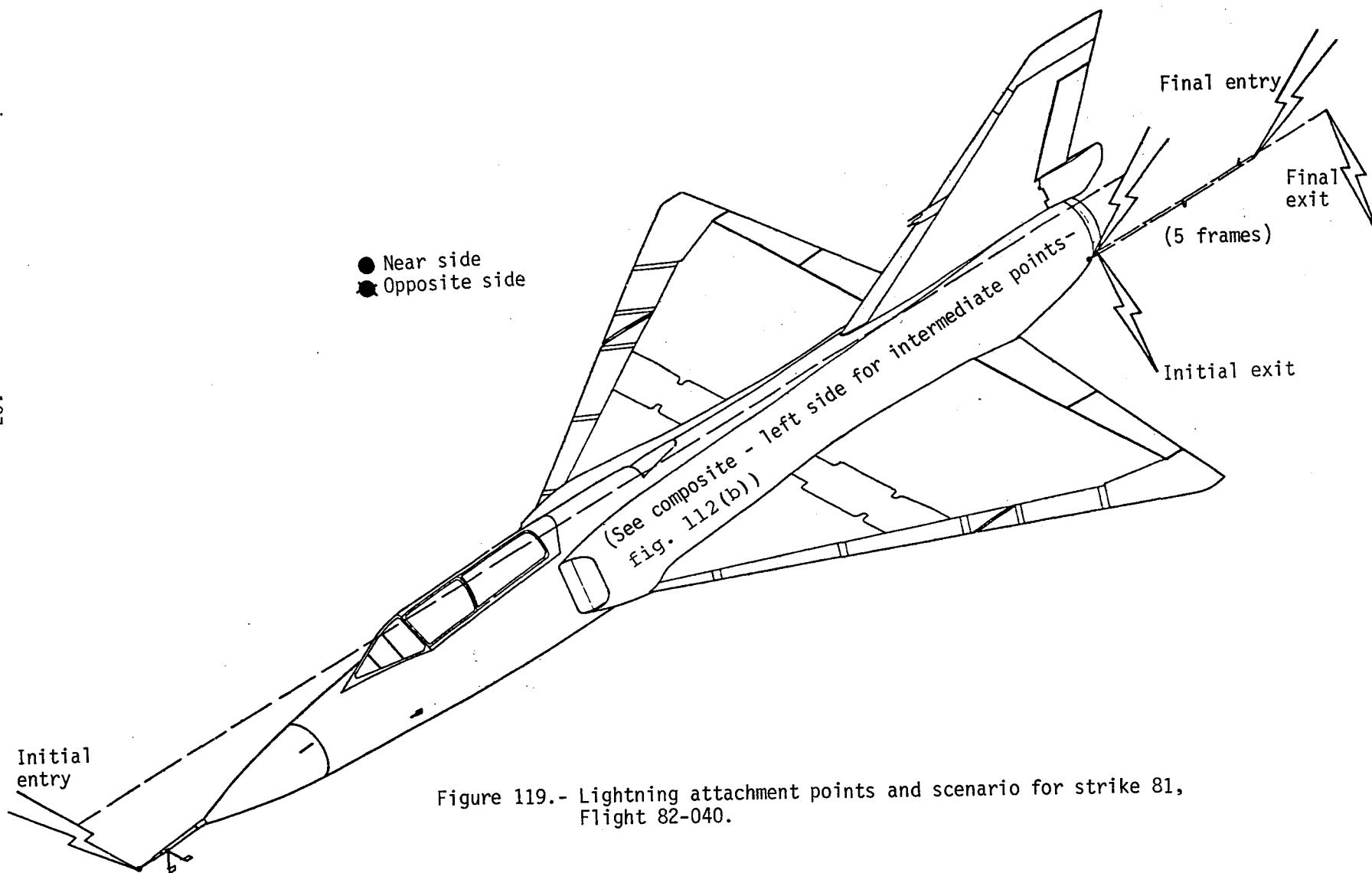
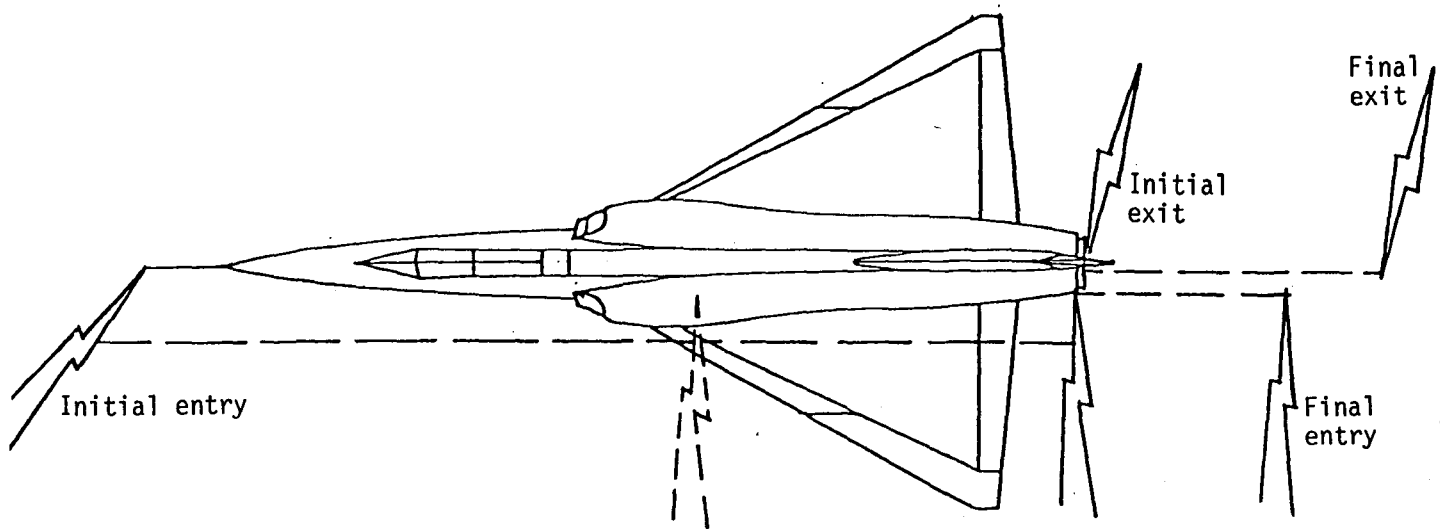
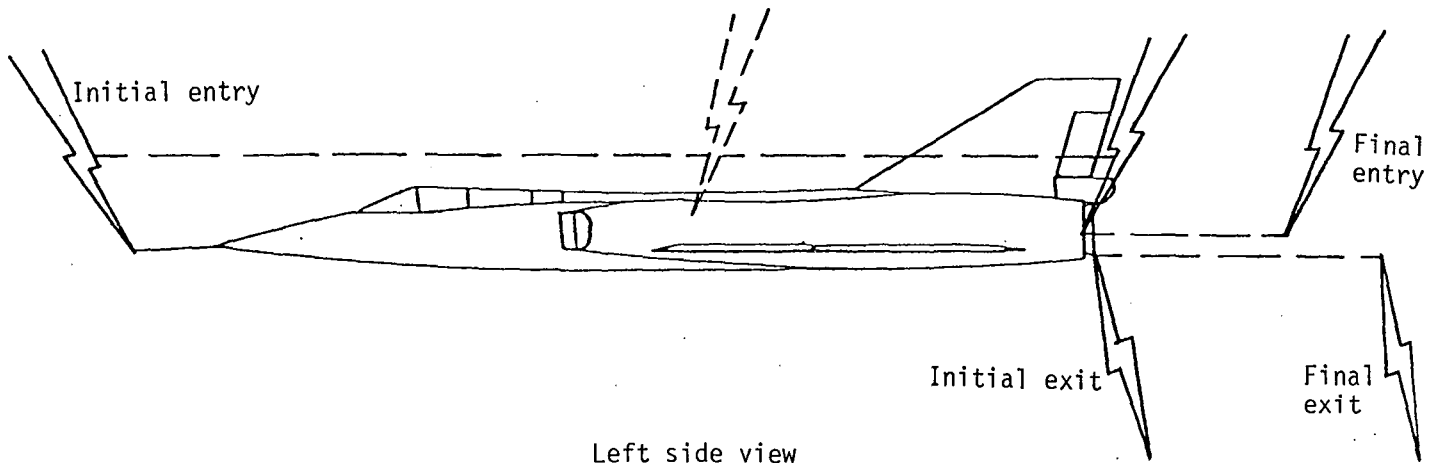


Figure 119.- Lightning attachment points and scenario for strike 81, Flight 82-040.

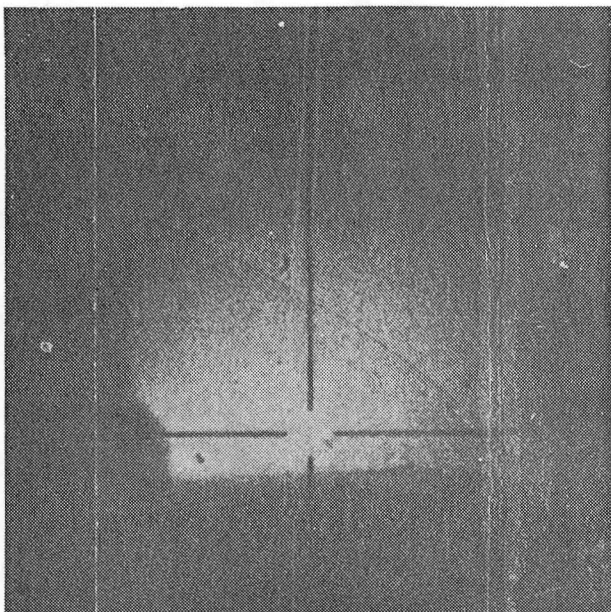


Top view

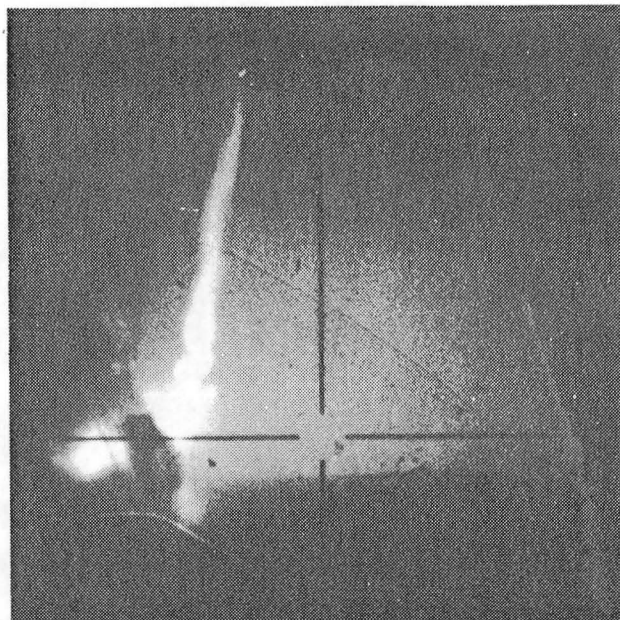


Left side view

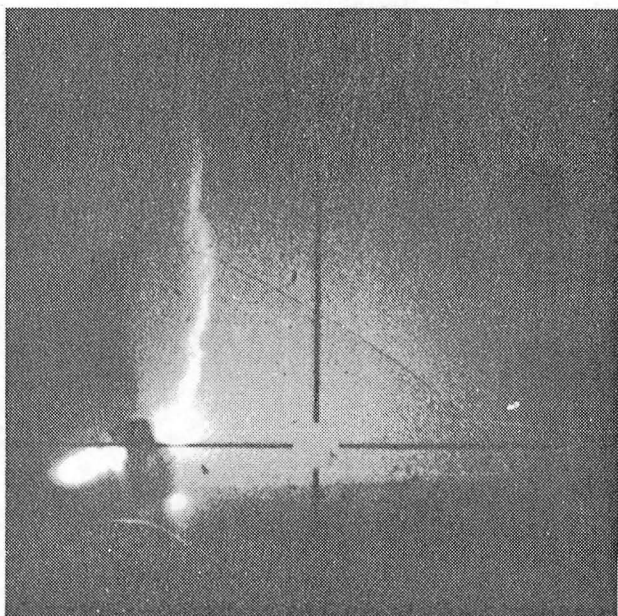
Figure 120.- Lightning attachment point scenario for strike 81, Flight 82-040.



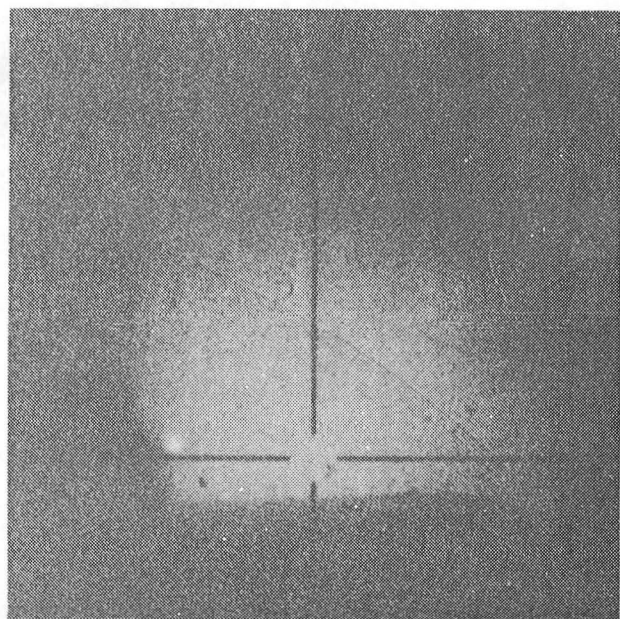
(a) Frame 1 of 5.



(b) Frame 2 of 5.

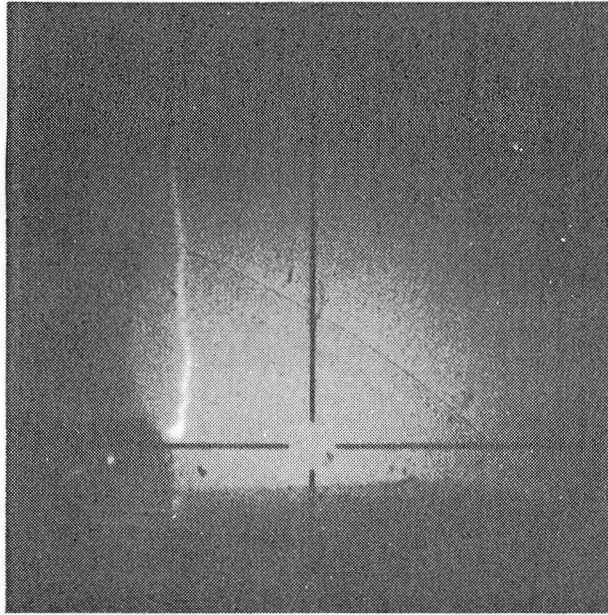


(c) Frame 3 of 5.



(d) Frame 4 of 5.

Figure 121. - Strike 81, Flight 82-040, aft camera.



(e) Frame 5 of 5.

Figure 121. - Concluded.

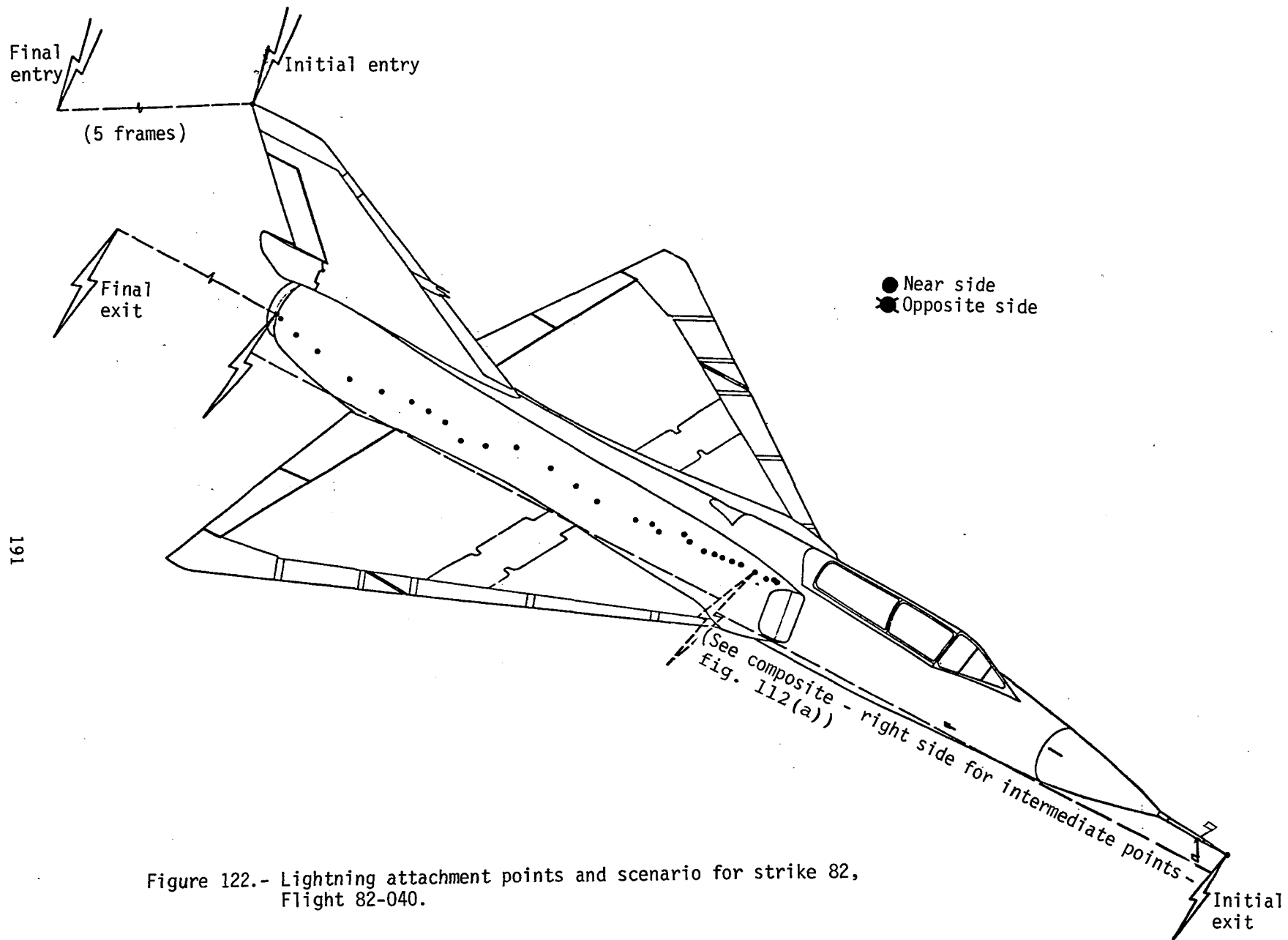
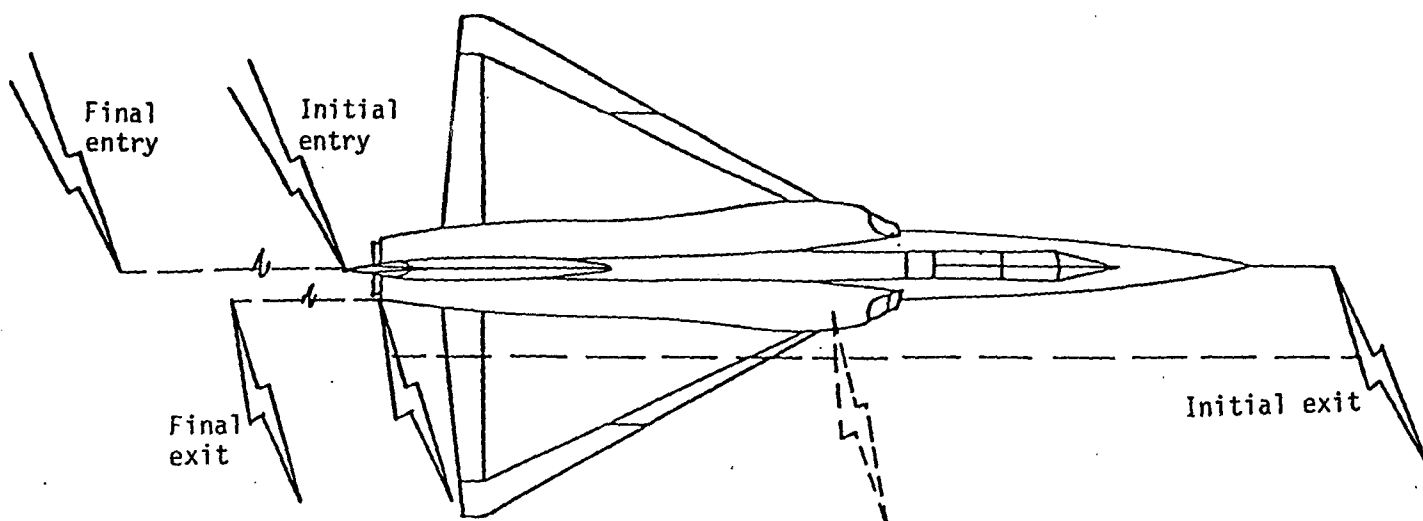
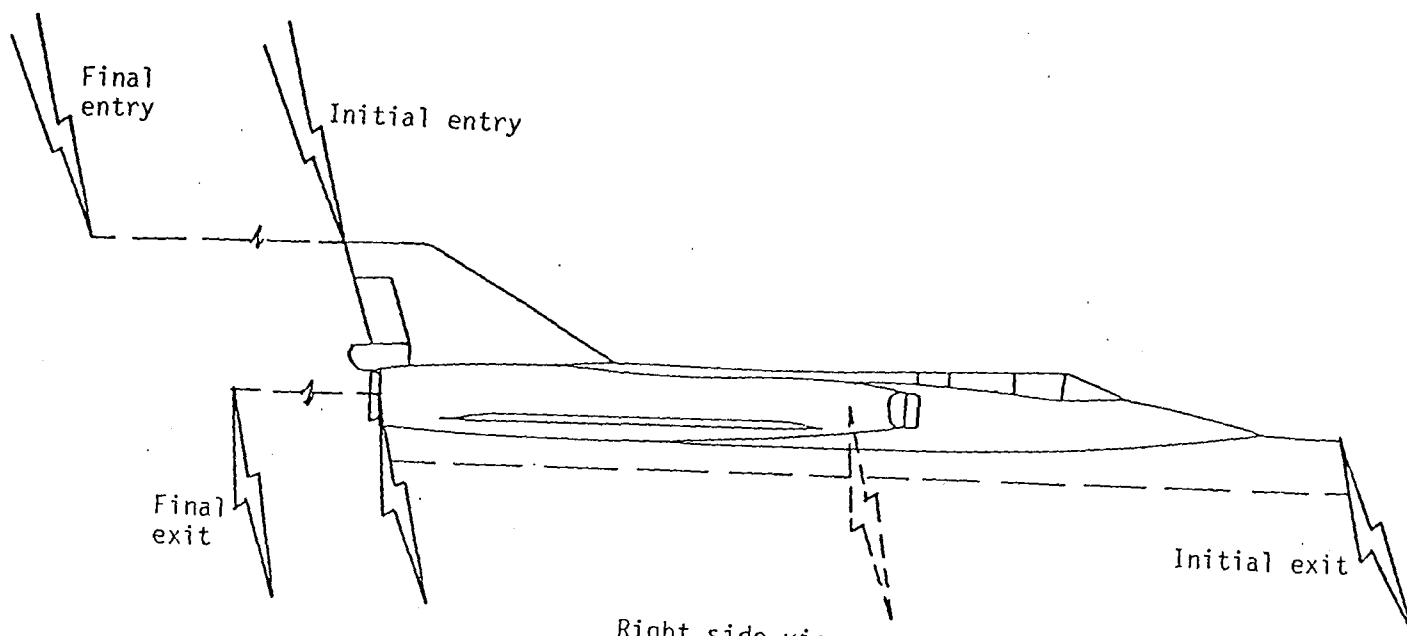


Figure 122.- Lightning attachment points and scenario for strike 82, Flight 82-040.

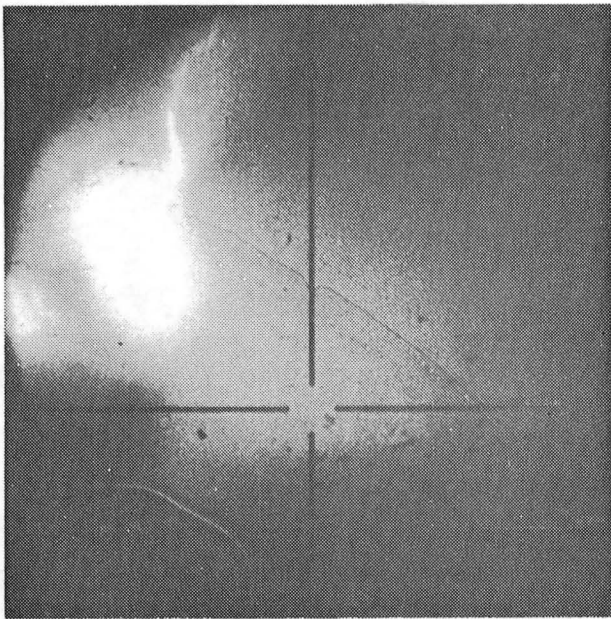


Top view

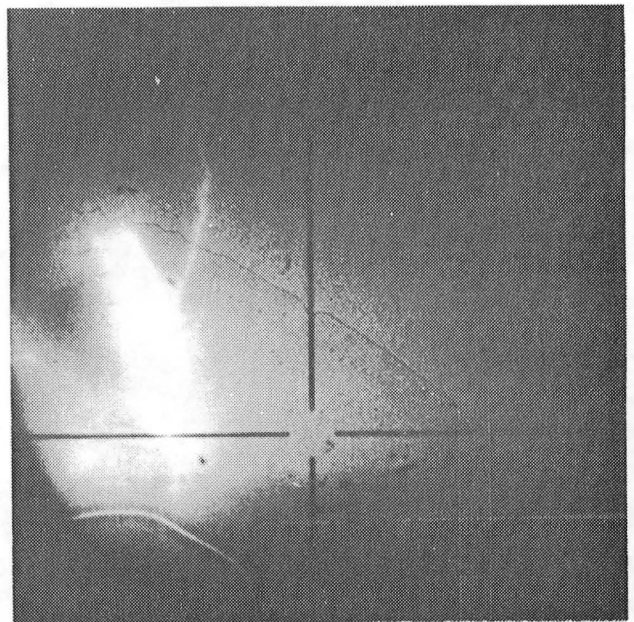


Right side view

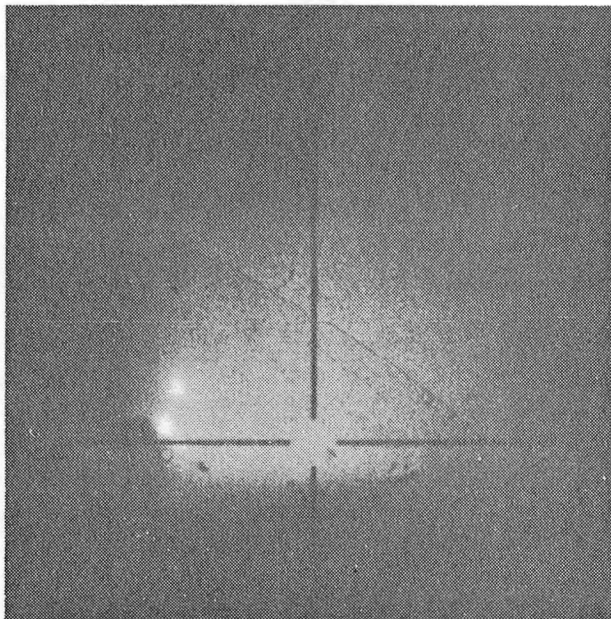
Figure 123.- Lightning attachment point scenario for strike 82,
Flight 82-040.



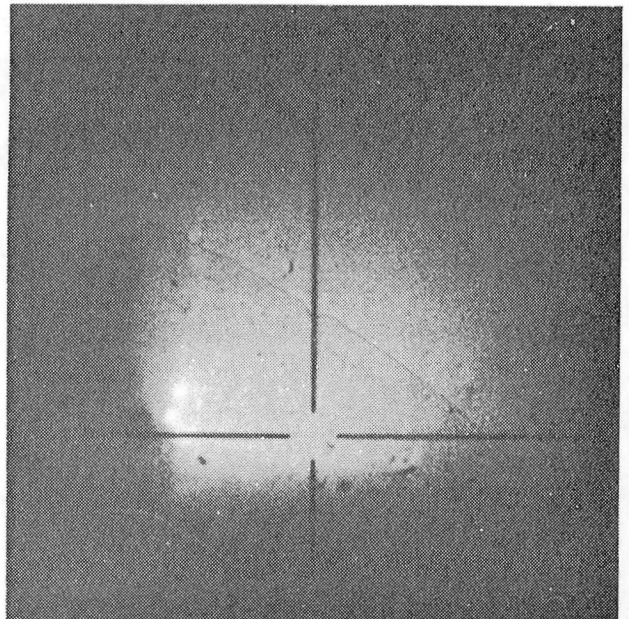
(a) Frame 1 of 5.



(b) Frame 2 of 5.

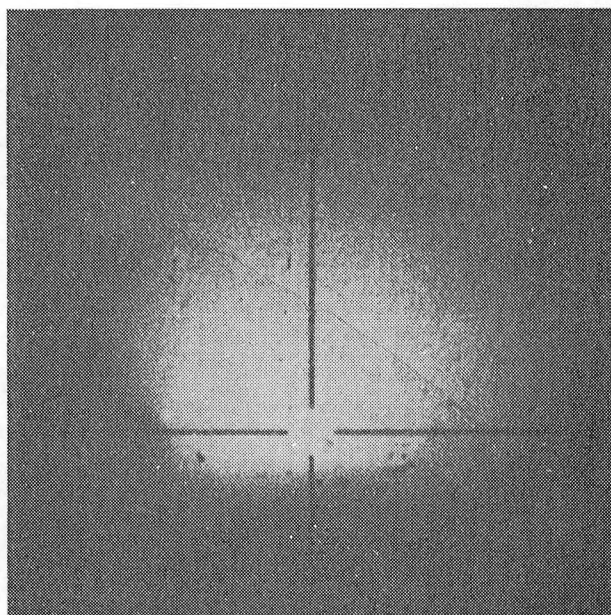


(c) Frame 3 of 5.



(d) Frame 4 of 5.

Figure 124. - Strike 82, Flight 82-040, aft camera.



(e) Frame 5 of 5.

Figure 124. - Concluded.

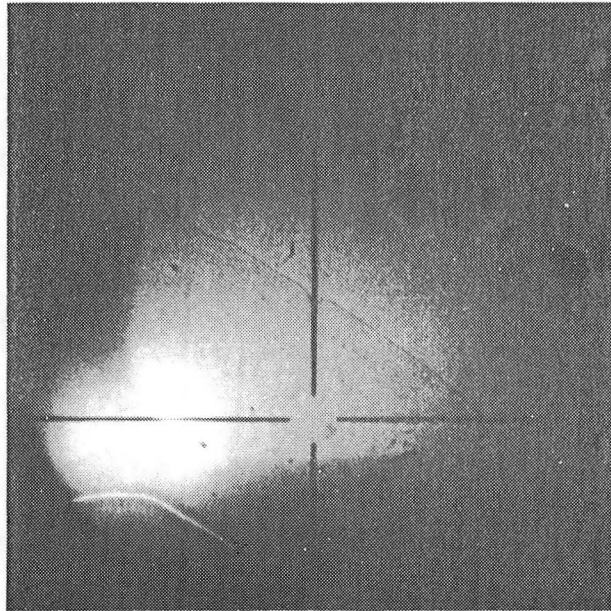
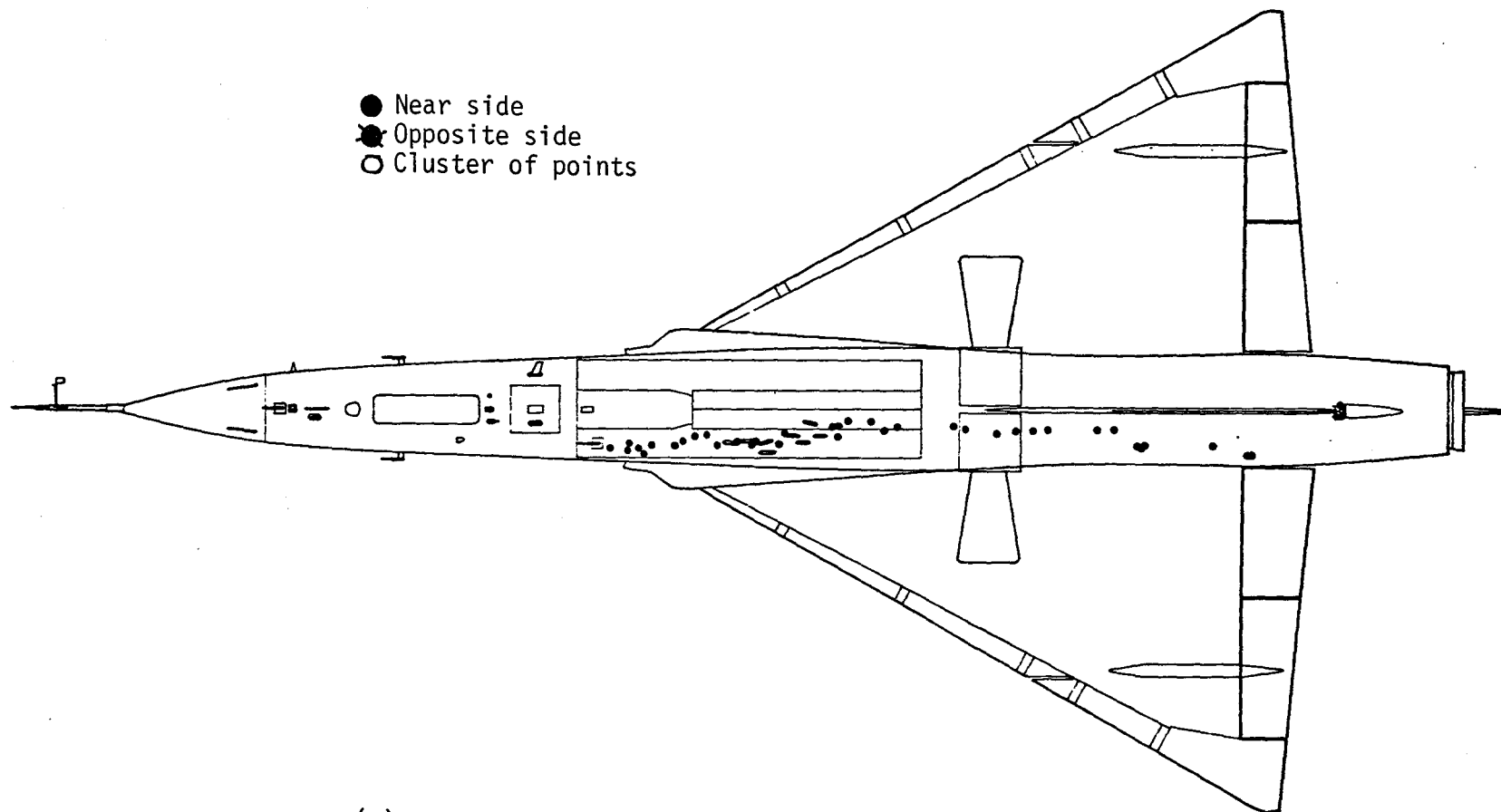
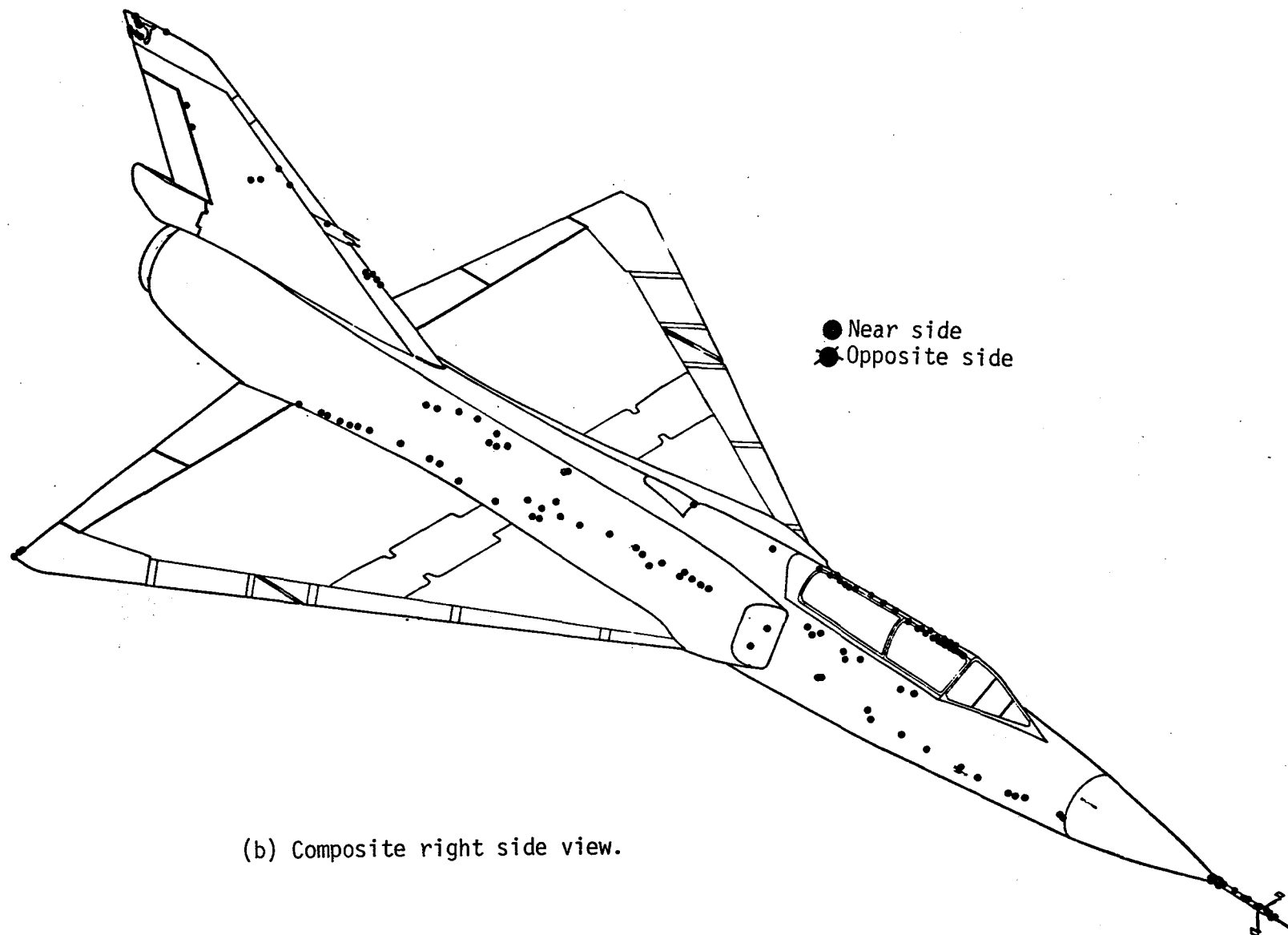


Figure 125. - Strike 83, Flight 82-040, aft camera.



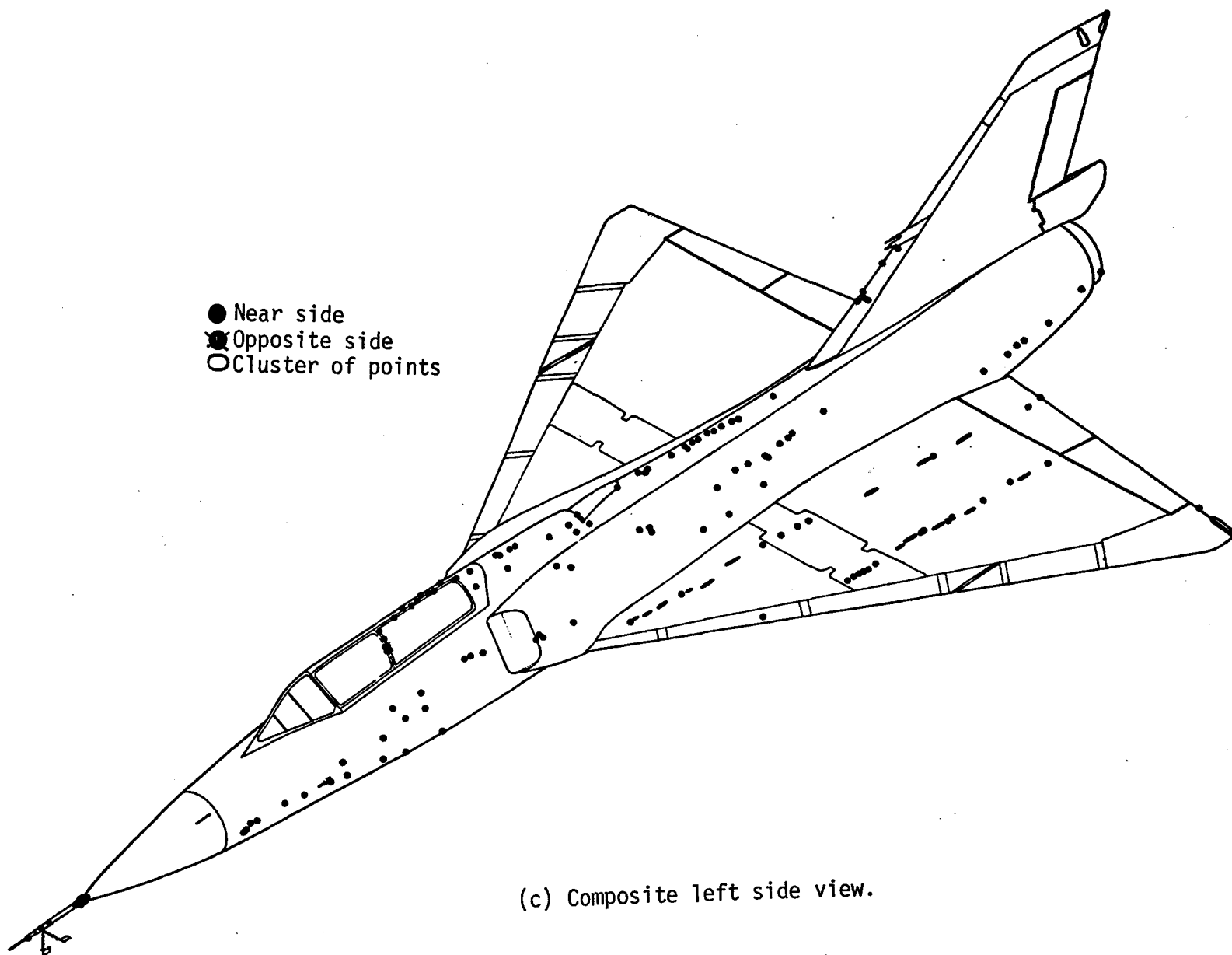
(a) Composite bottom view.

Figure 126.- Lightning attachment points for strikes 126-148,
Flight 82-044.



(b) Composite right side view.

Figure 126.- Continued.



(c) Composite left side view.

Figure 126.- Concluded.

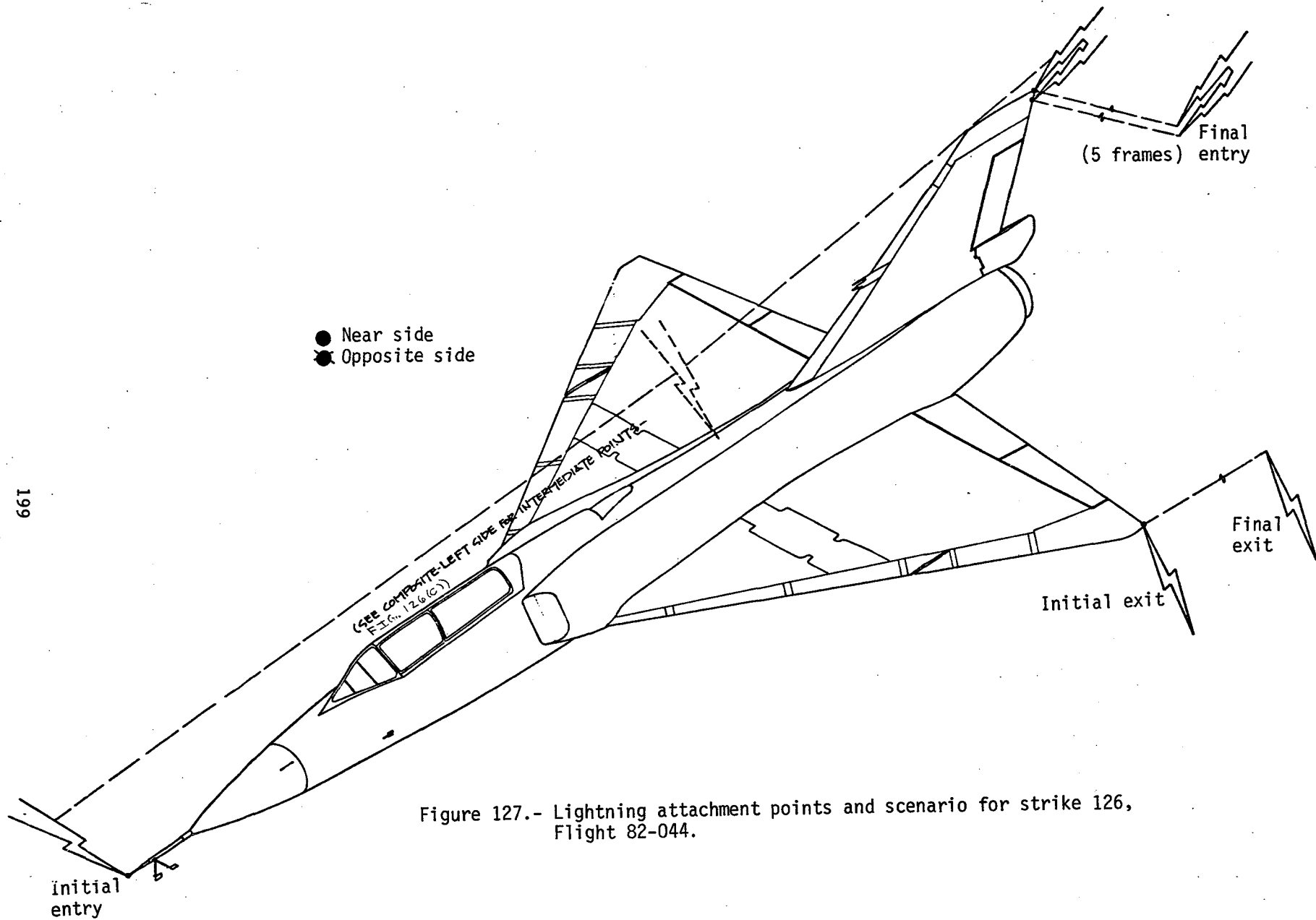


Figure 127.- Lightning attachment points and scenario for strike 126, Flight 82-044.

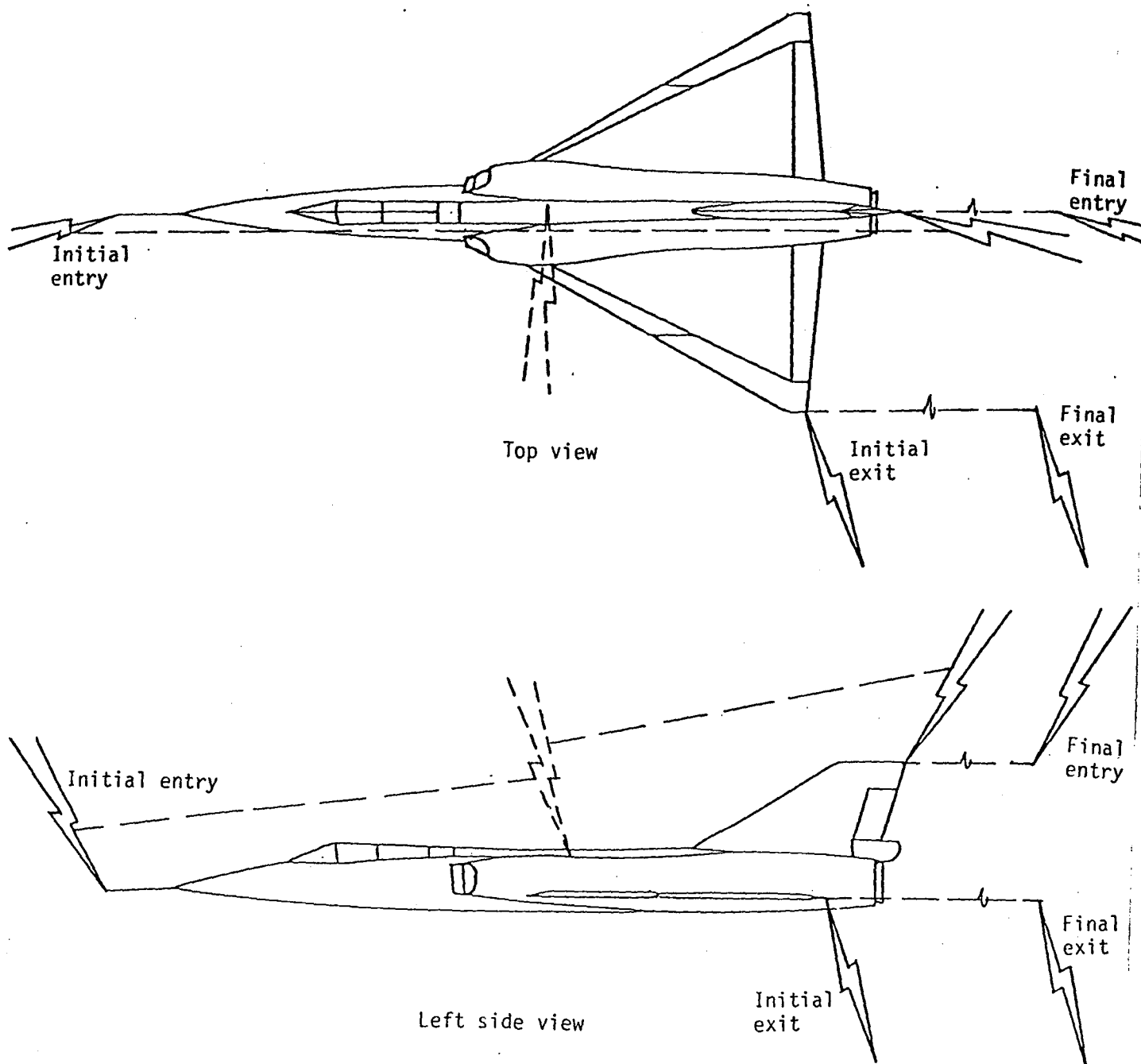


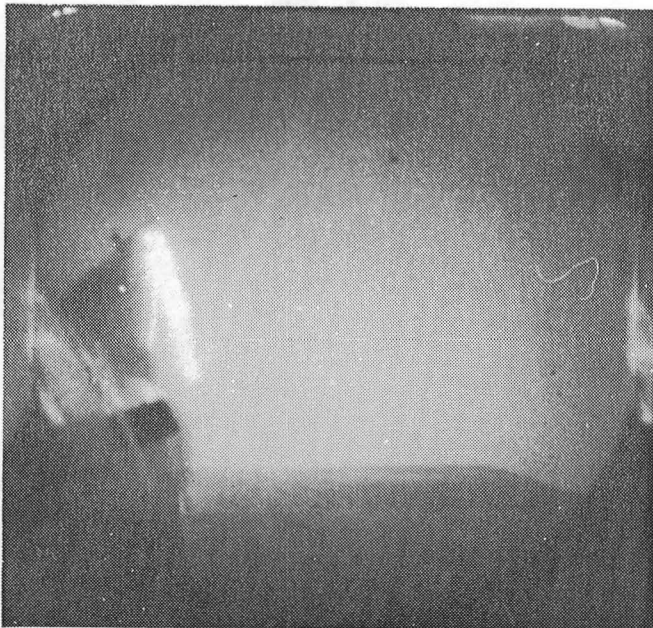
Figure 128.- Lightning attachment point scenario for strike 126, Flight 82-044.



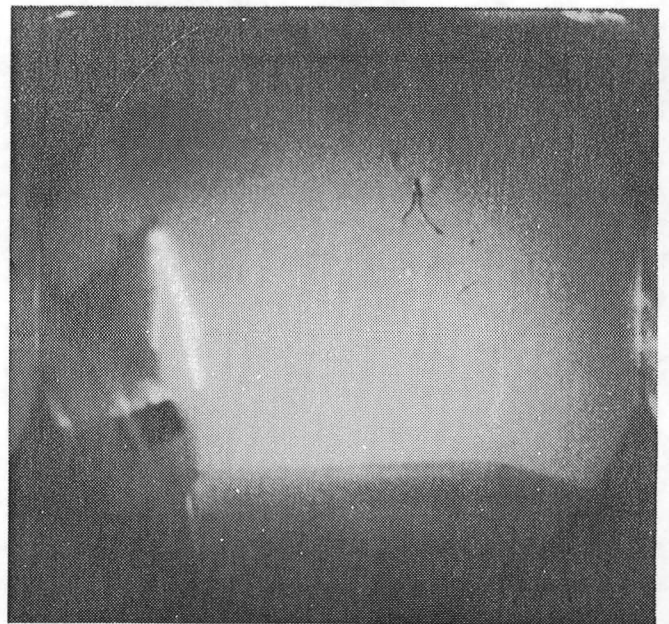
(a) Frame 1 of 5.



(b) Frame 2 of 5.



(c) Frame 3 of 5.



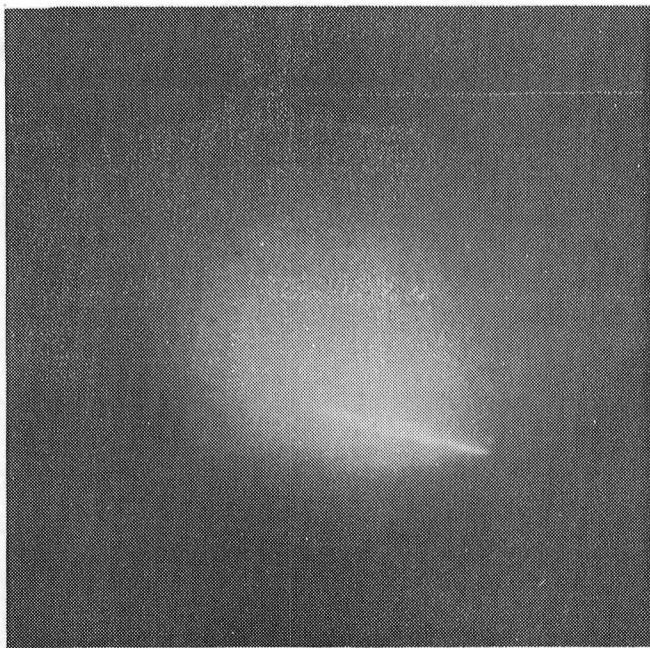
(d) Frame 4 of 5.

Figure 129. - Strike 126, Flight 82-044, aft camera.



(e) Frame 5 of 5.

Figure 129. - Concluded.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 130. - Strike 127, Flight 82-044, aft camera.

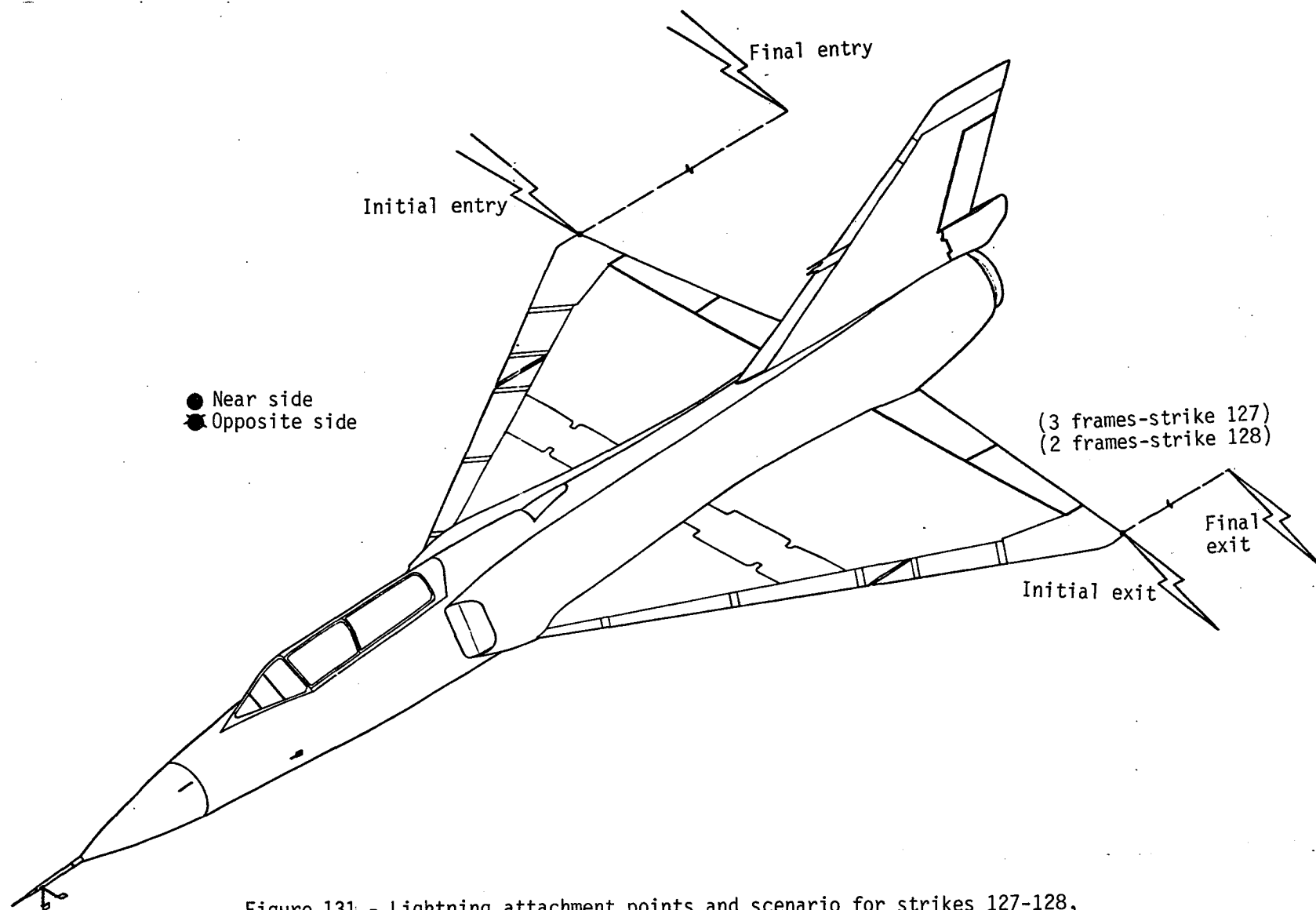


Figure 131.- Lightning attachment points and scenario for strikes 127-128, Flight 82-044.

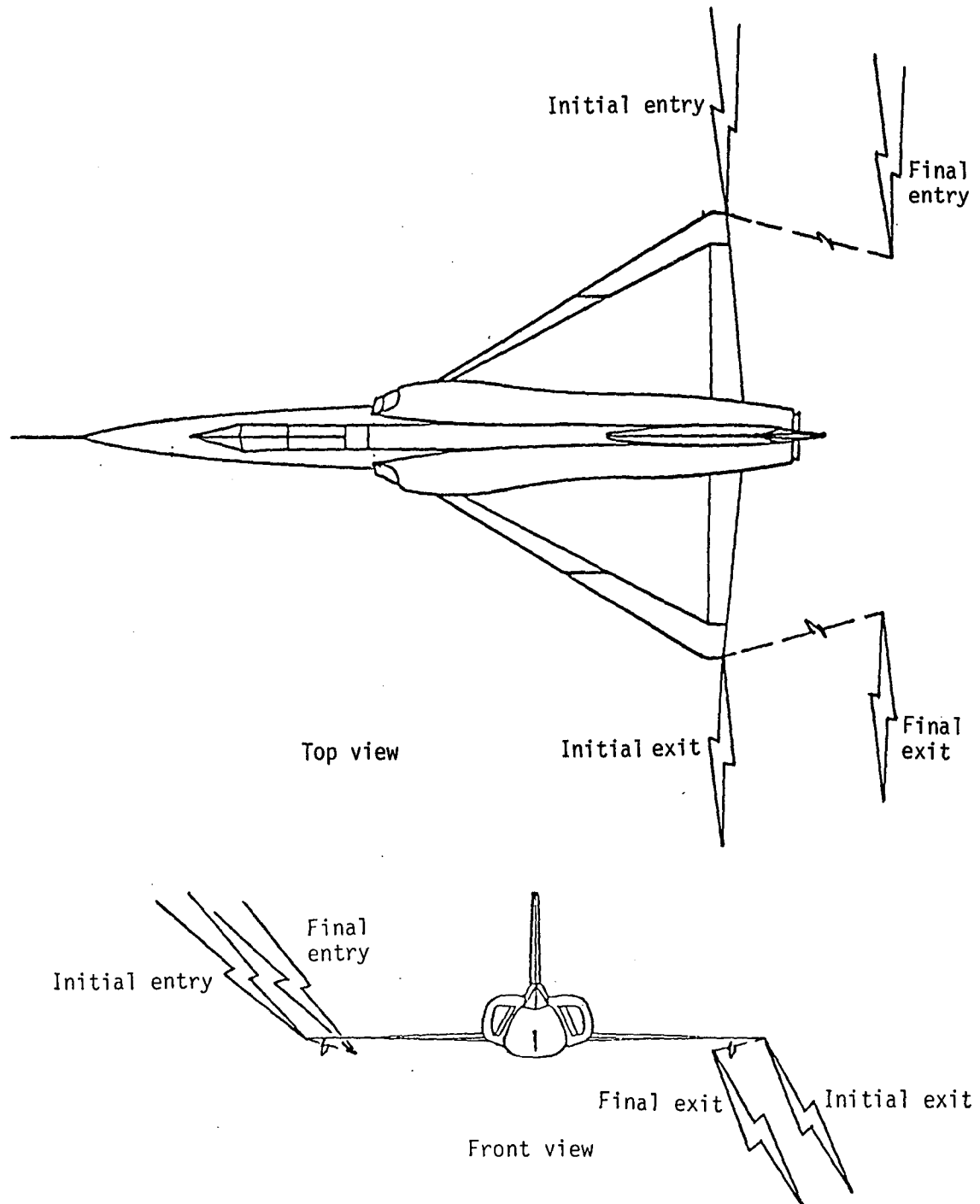
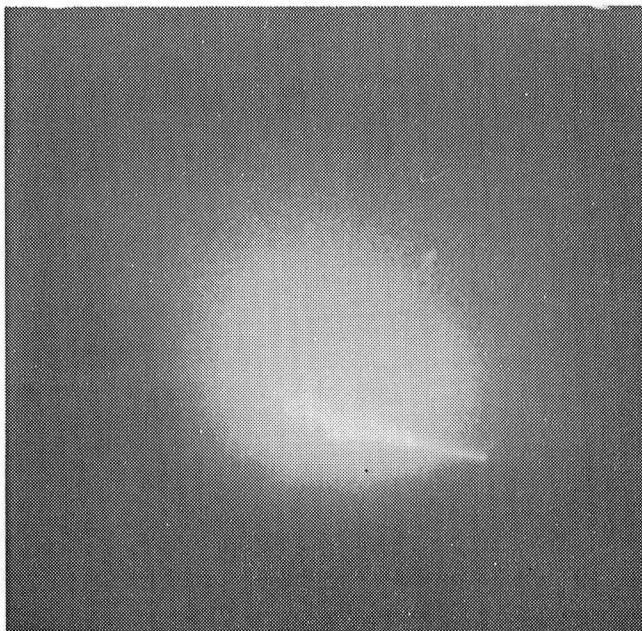
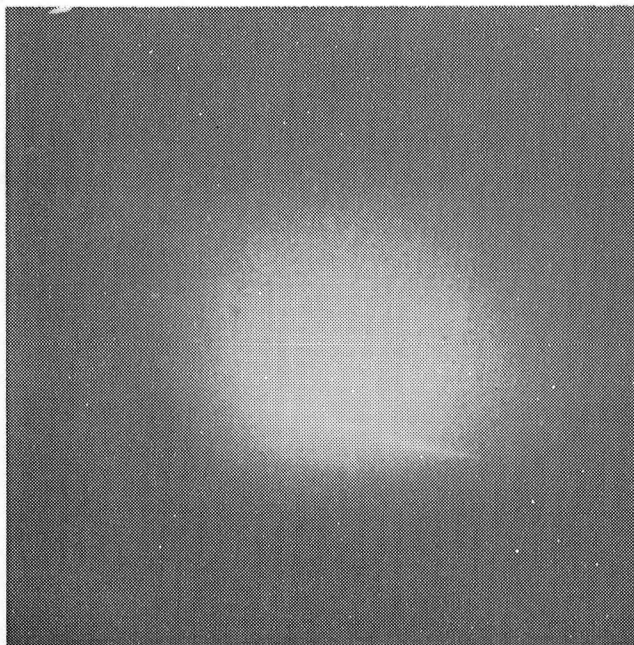


Figure 132.- Lightning attachment scenario for strike 127-128, Flight 82-044.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 133. - Strike 128, Flight 82-044, aft camera.

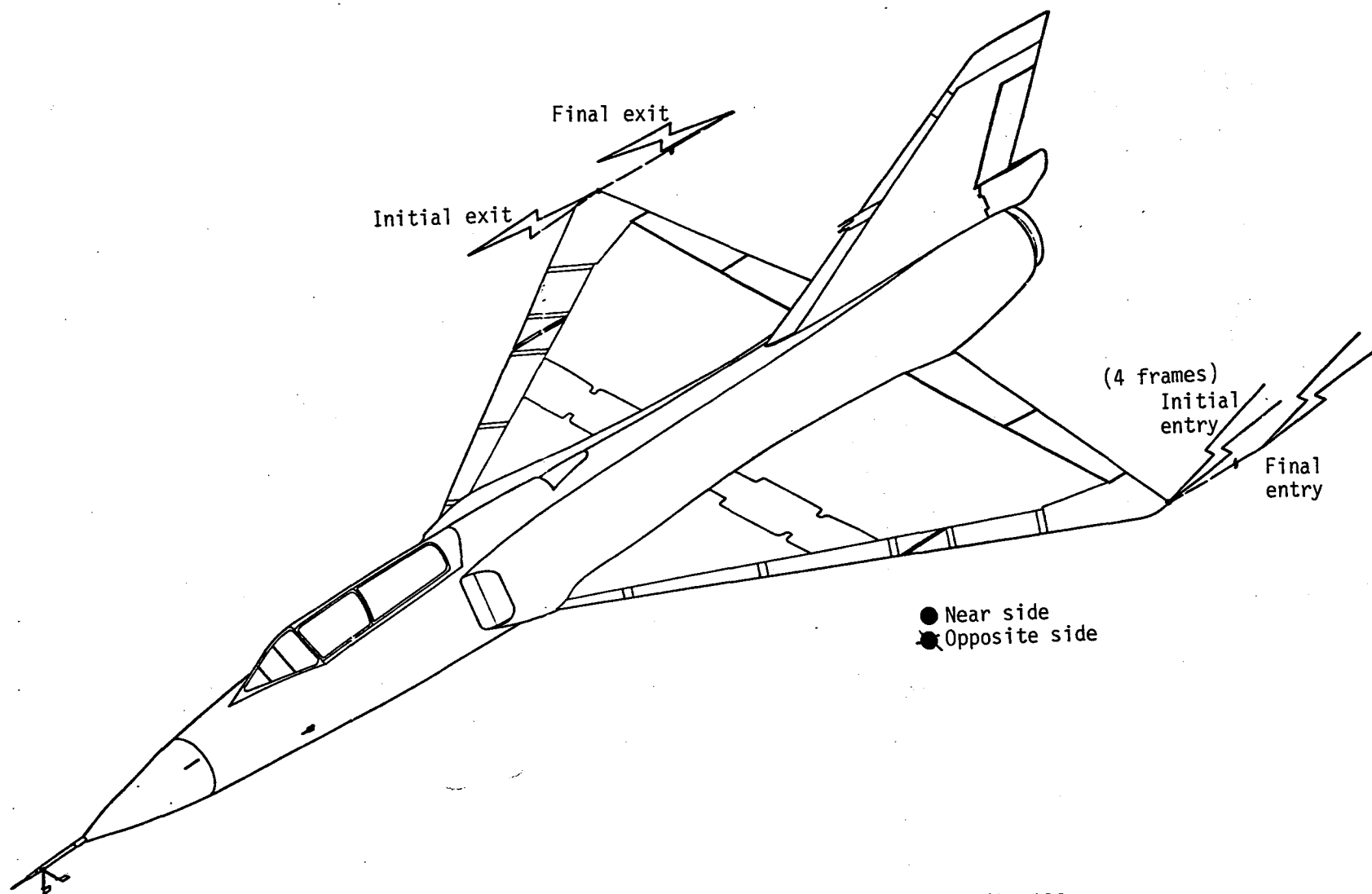


Figure 134.- Lightning attachment points and scenario for strike 130, Flight 82-044.

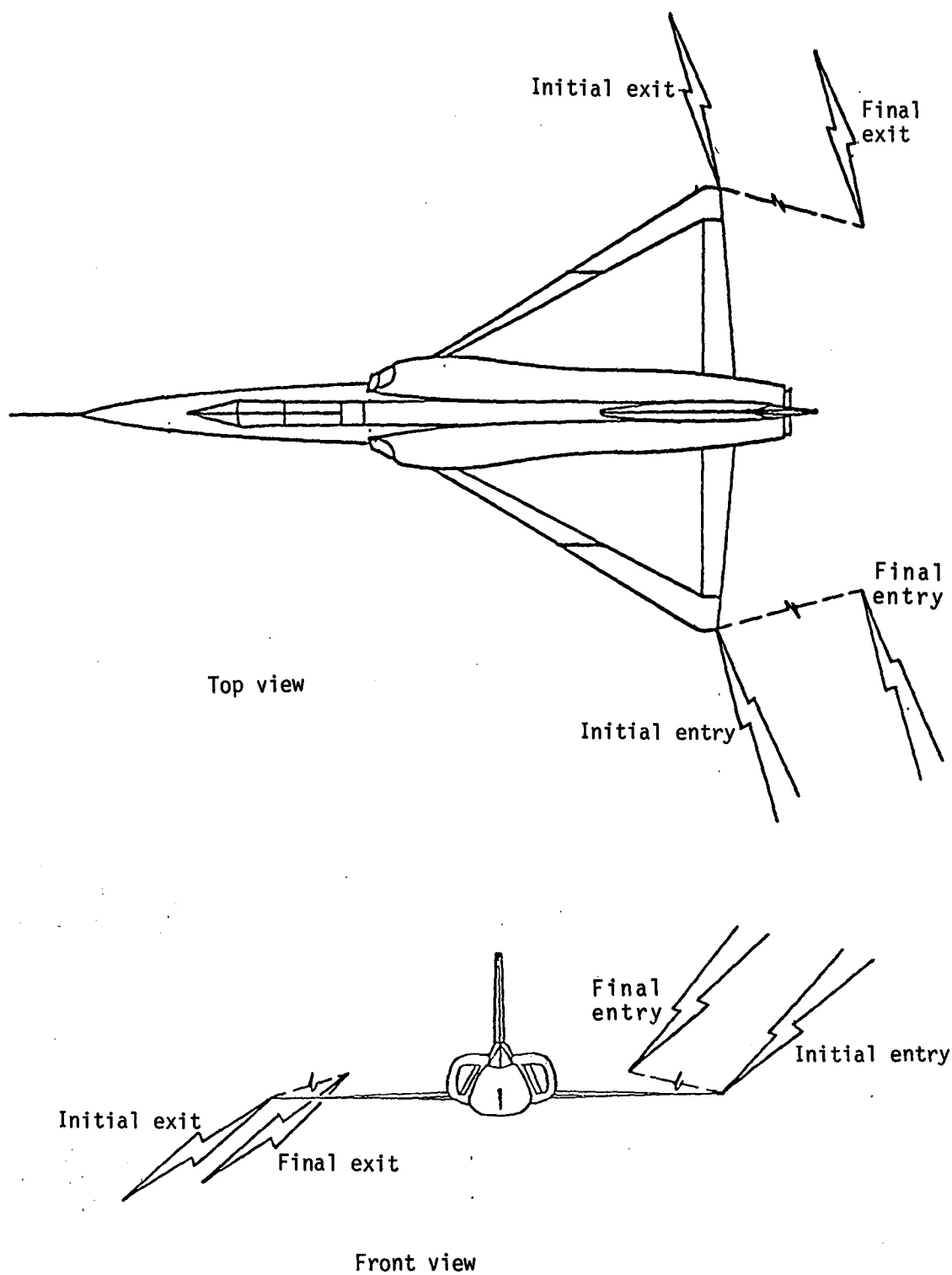
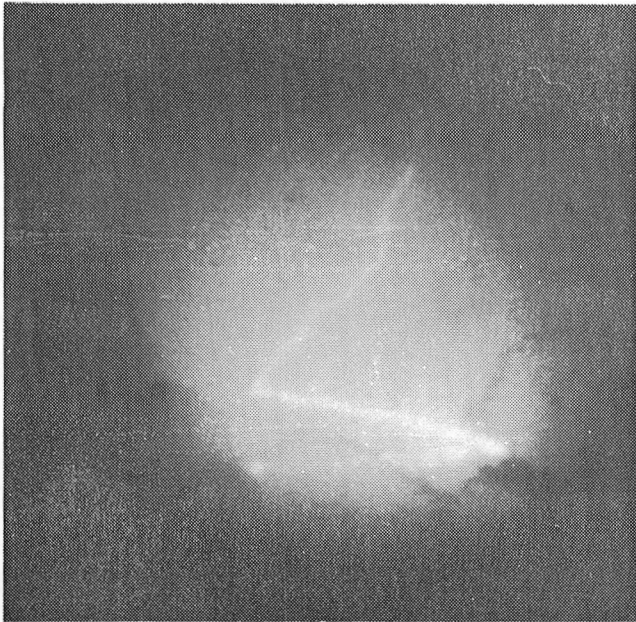
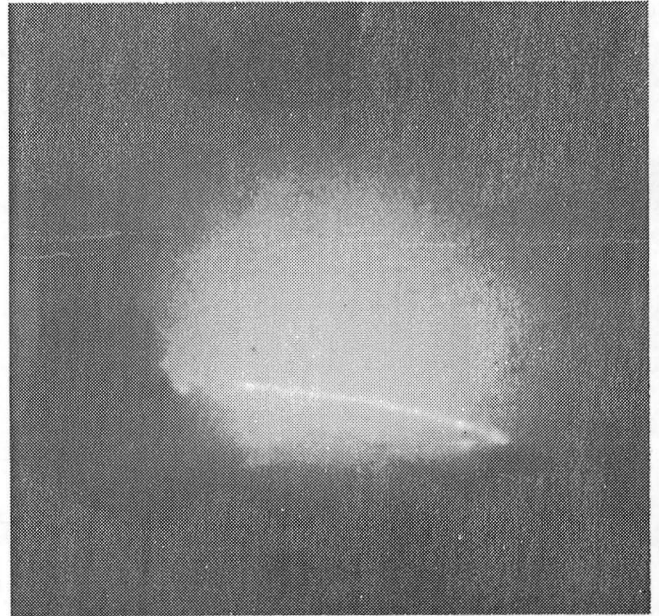


Figure 135.- Lightning attachment point scenario for strike 130, Flight 82-044.



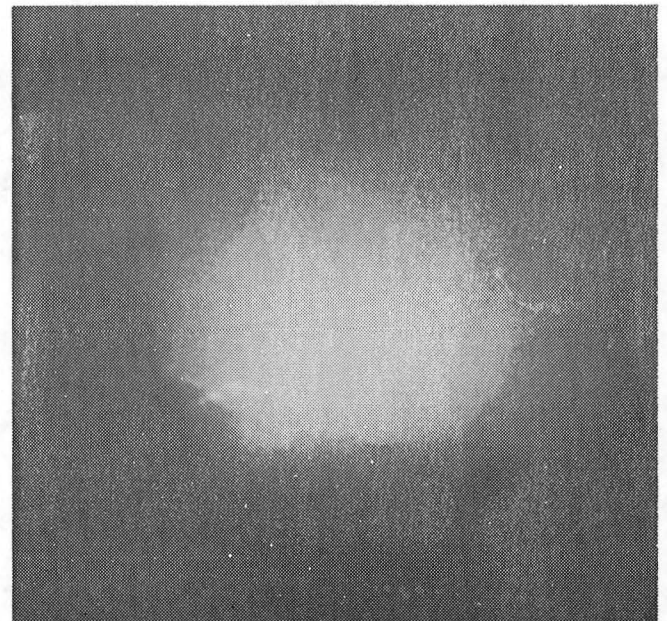
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.



(d) Frame 4 of 4.

Figure 136. - Strike 130, Flight 82-044, aft camera.

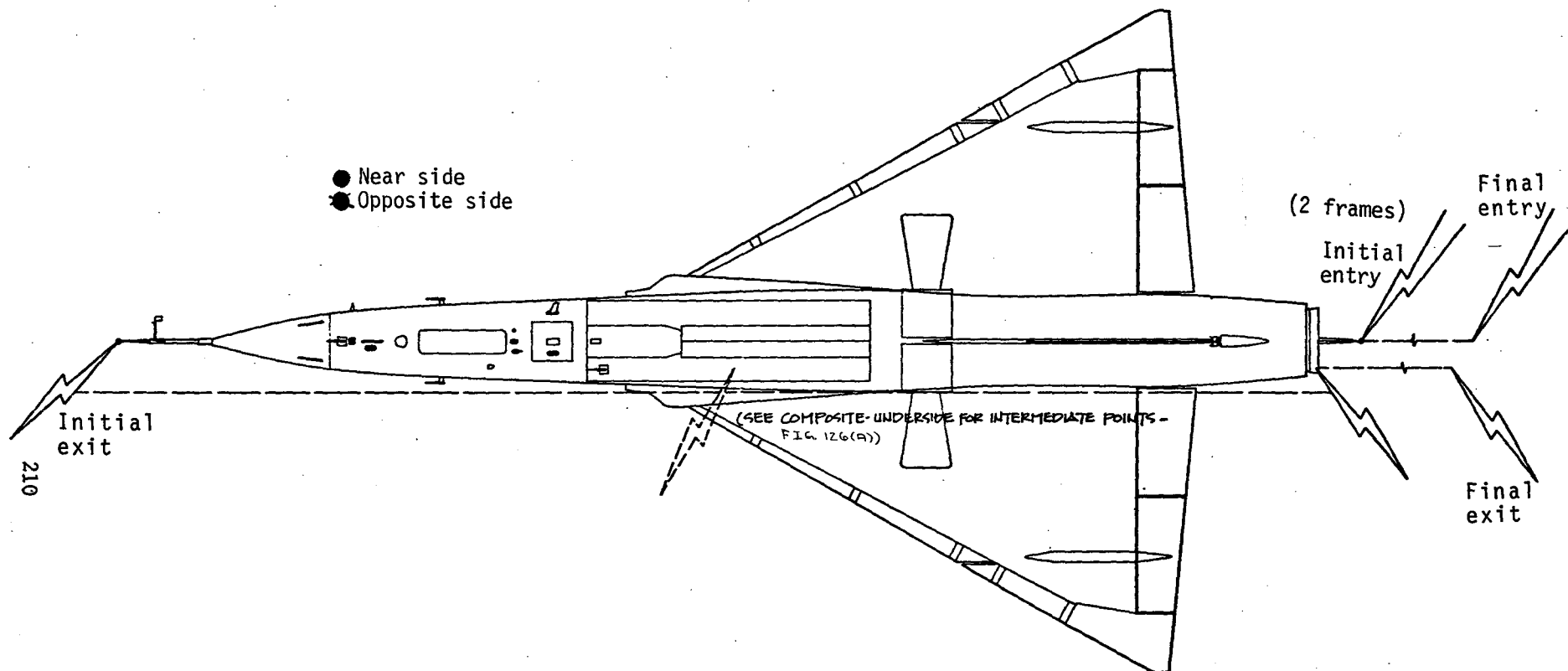


Figure 137.- Lightning attachment points and scenario for strike 131, Flight 82-044.

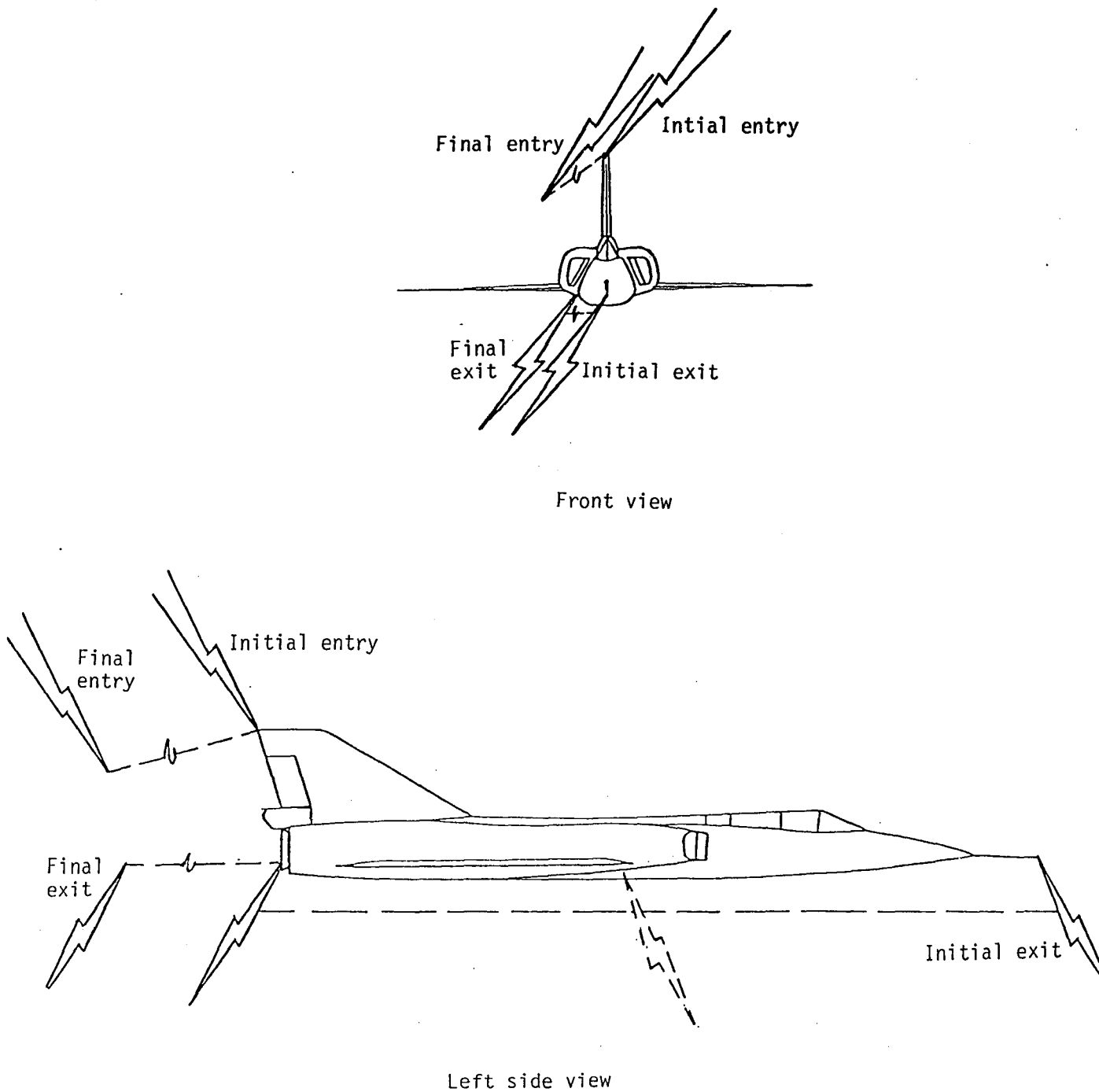
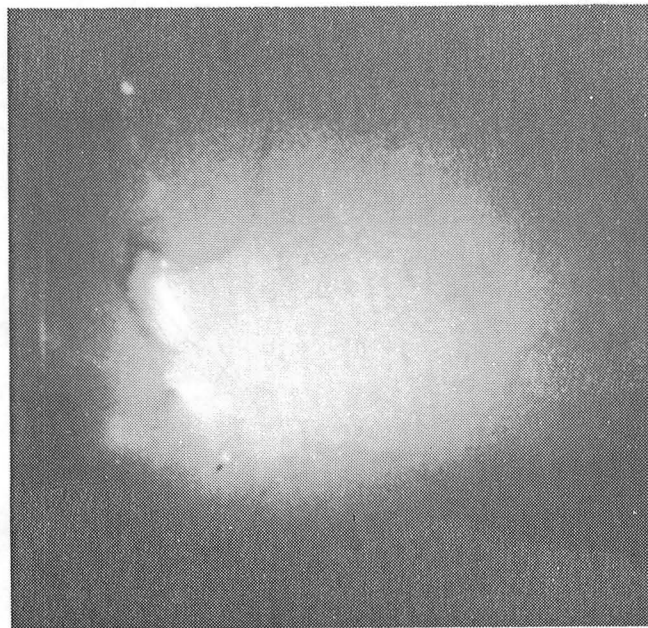
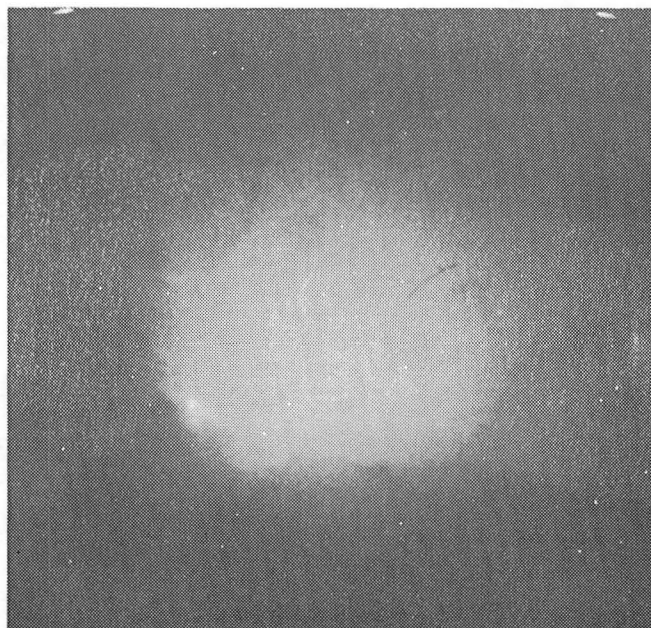


Figure 138.- Lightning attachment point scenario for strike 131, Flight 82-044.

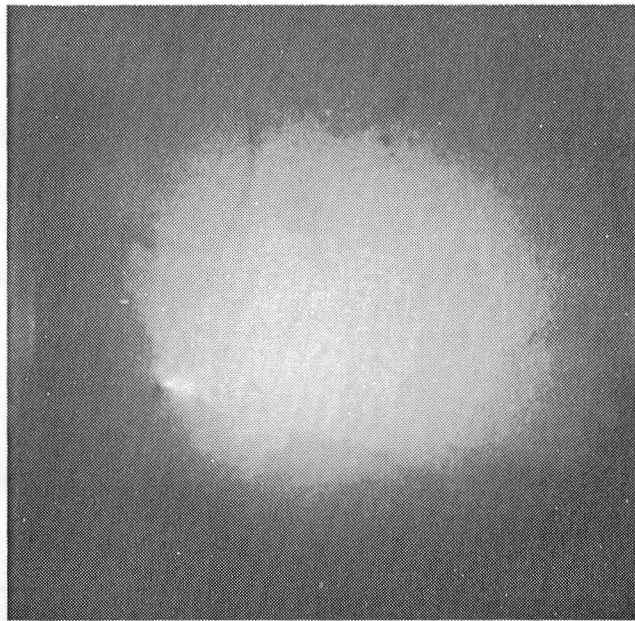


(a) Frame 1 of 2.

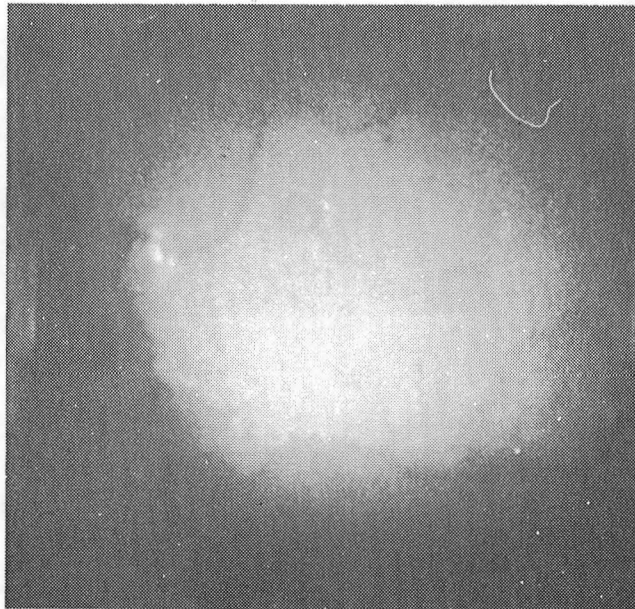


(b) Frame 2 of 2.

Figure 139. - Strike 131, Flight 82-044, aft camera.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 140. - Strike 132, Flight 82-044, aft camera.



Figure 141. - Strike 134, Flight 82-044, aft camera.

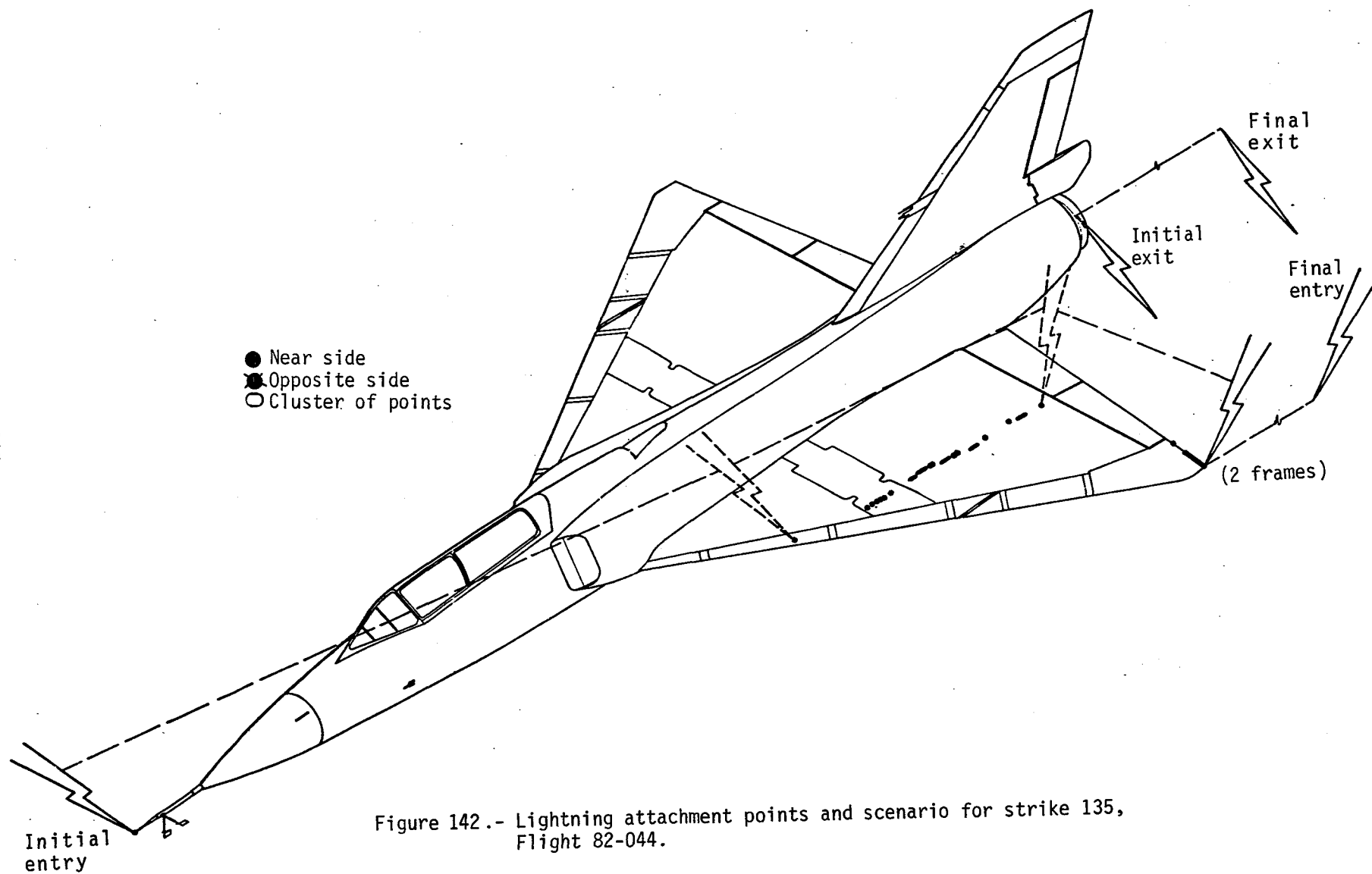


Figure 142.- Lightning attachment points and scenario for strike 135, Flight 82-044.

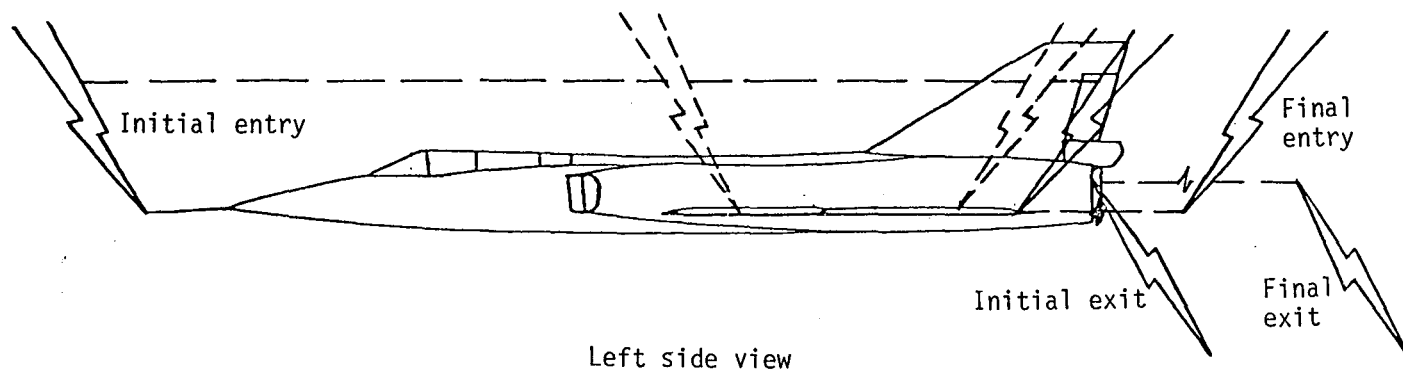
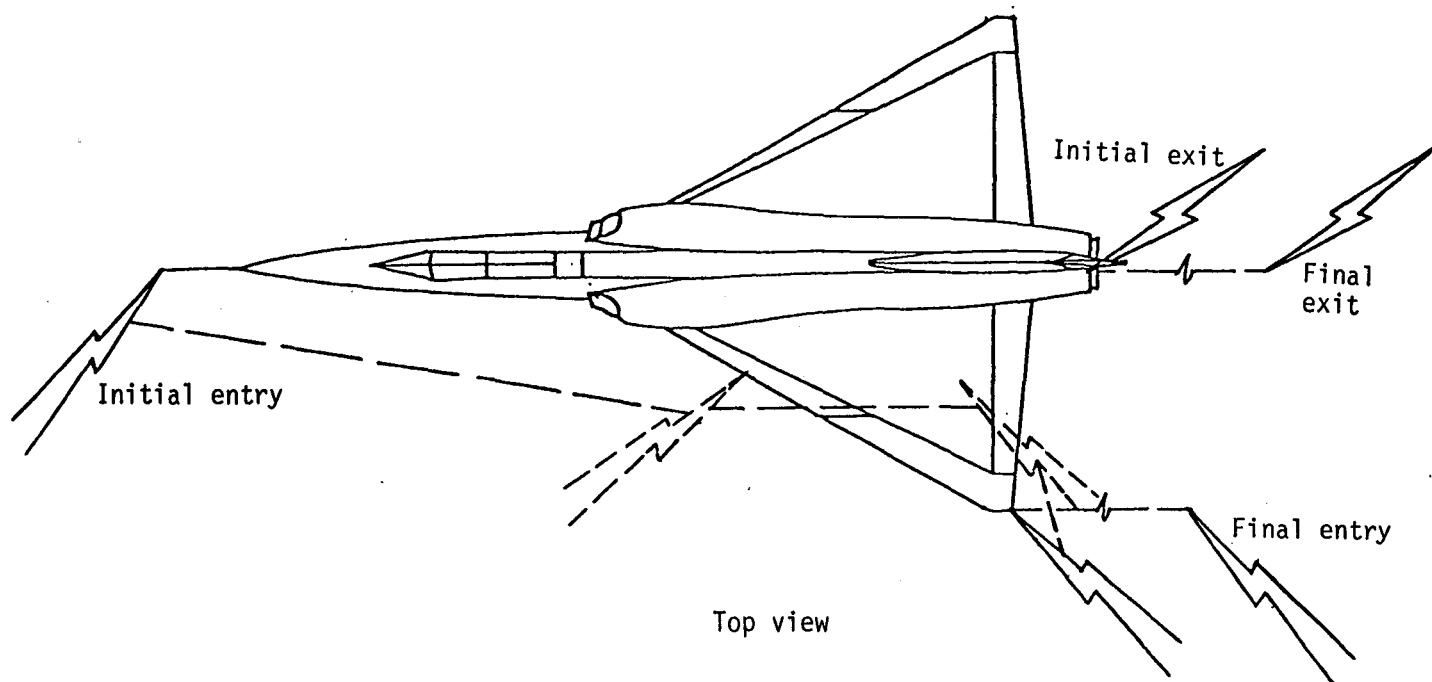
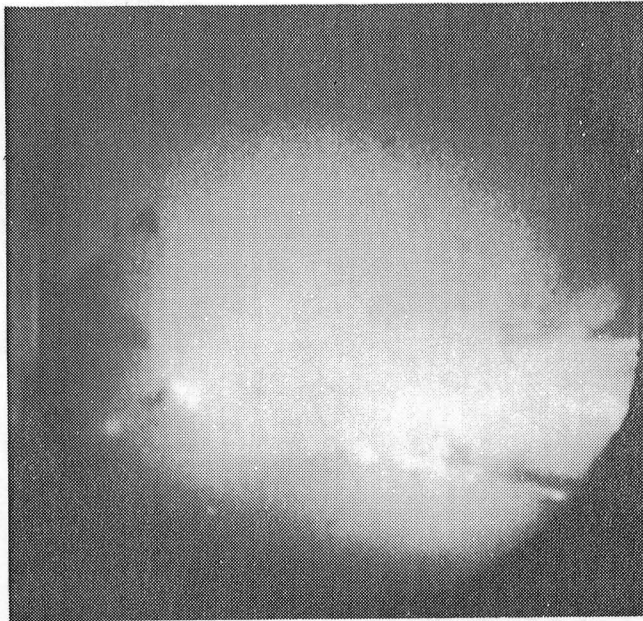
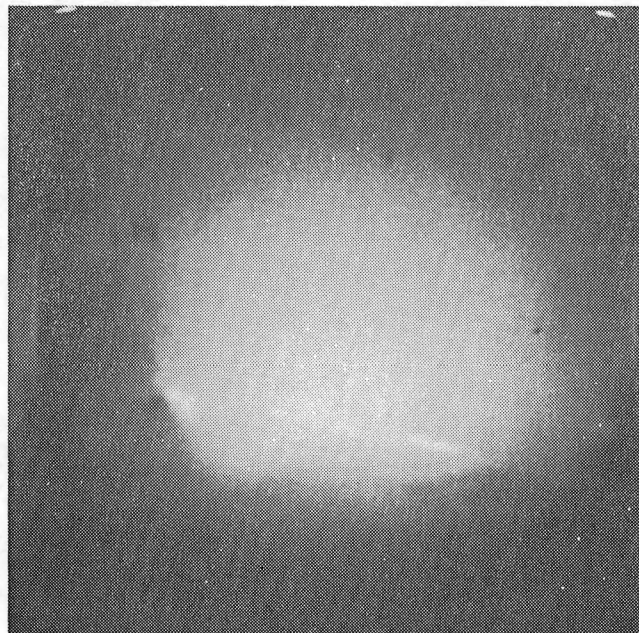


Figure 143.- Lightning attachment point scenario for strike 135, Flight 82-044.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 144. - Strike 135, Flight 82-044, aft camera.

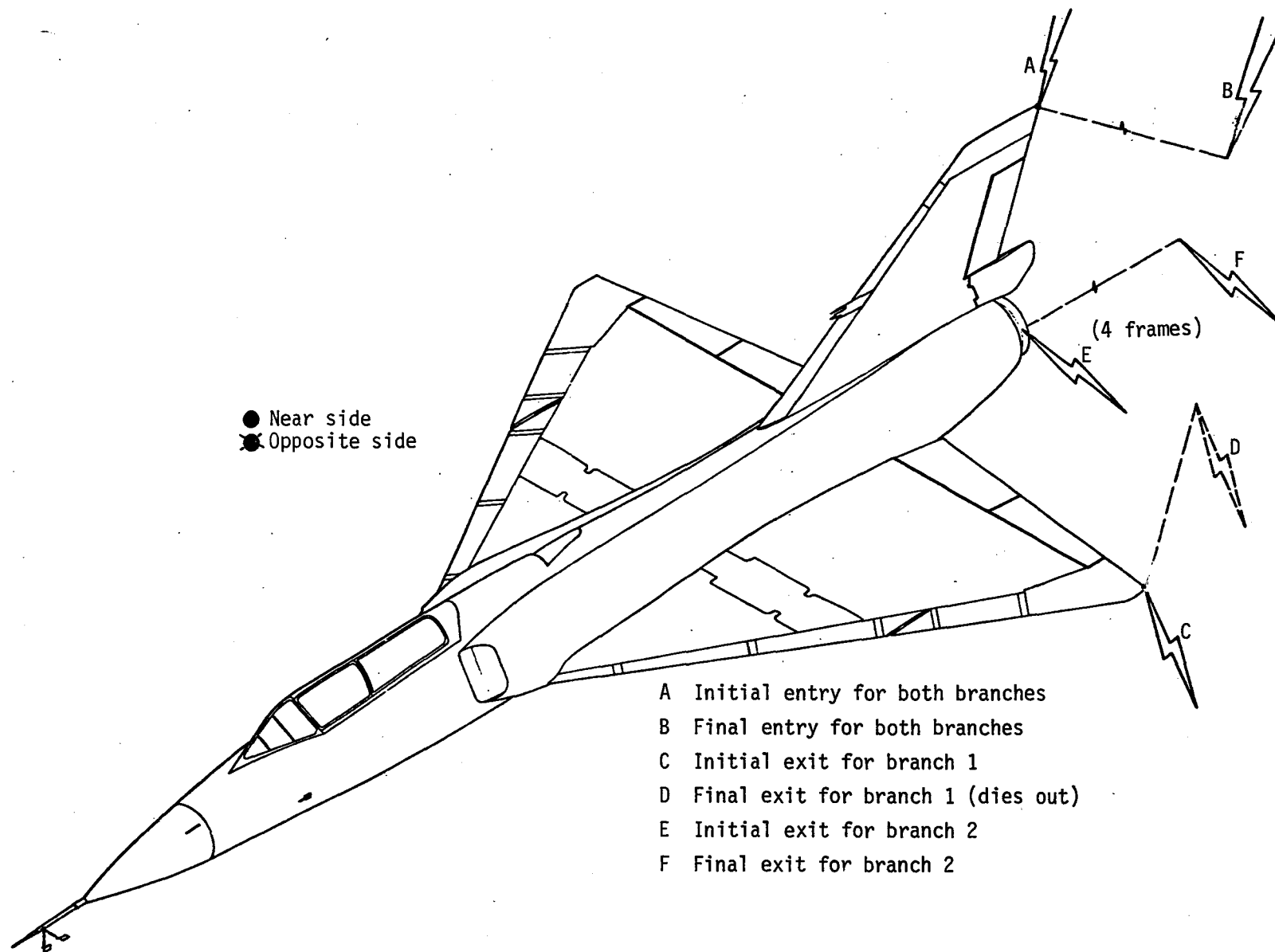
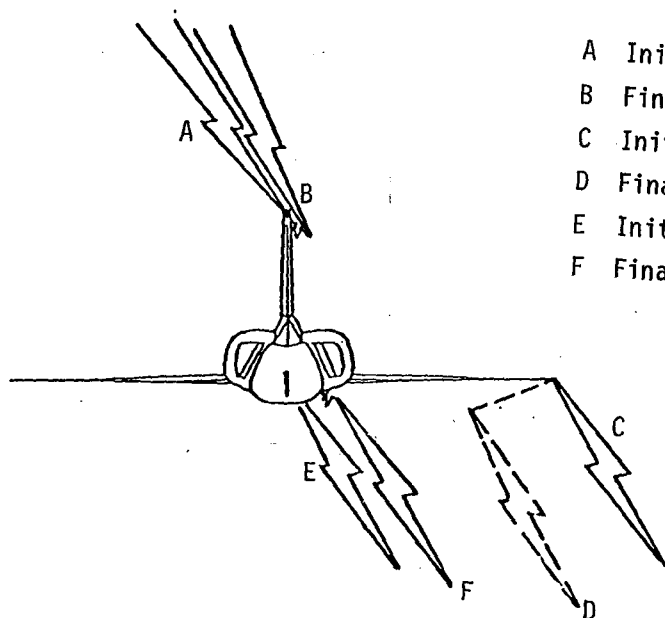
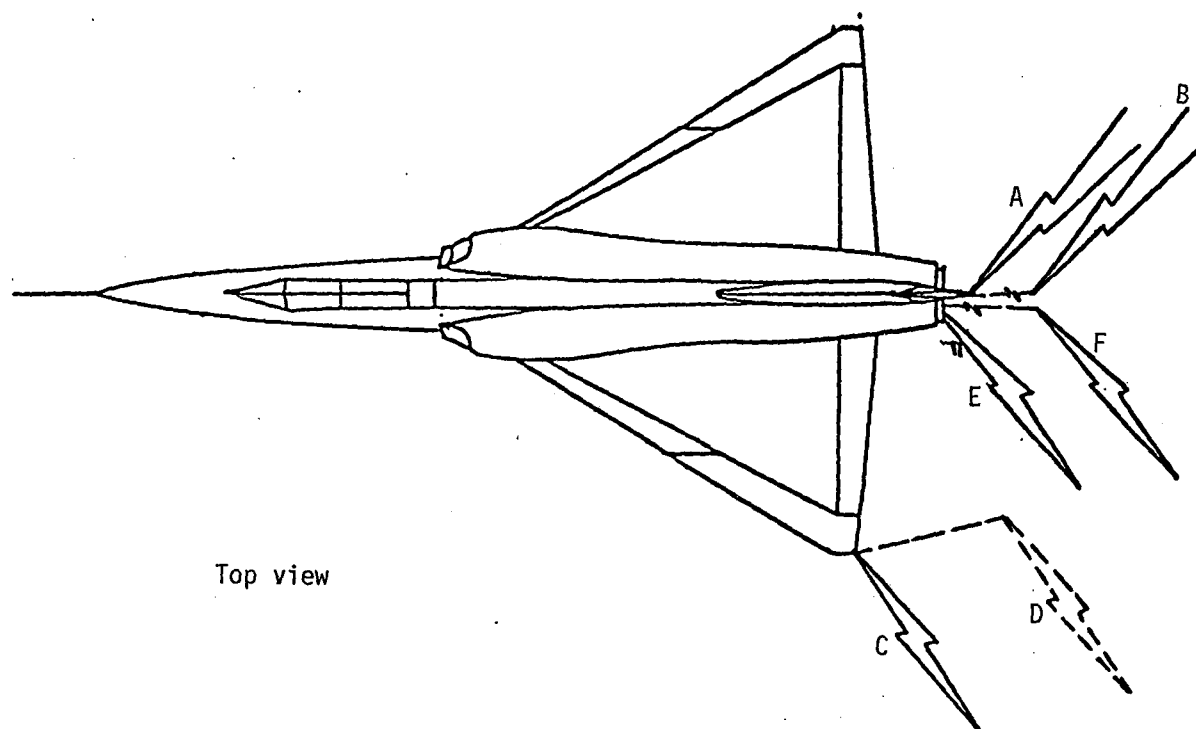
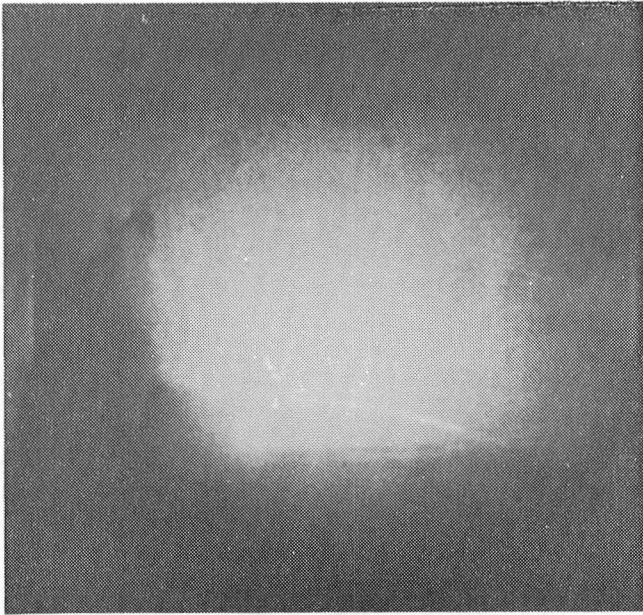


Figure 145.- Lightning attachment points and scenario for strike 136, Flight 82-044.



- A Initial entry for both branches
- B Final entry for both branches
- C Initial exit for branch 1
- D Final exit for branch 1 (dies out)
- E Initial exit for branch 2
- F Final exit for branch 2

Figure 146.- Lightning attachment point scenario for strike 136, Flight 82-044.



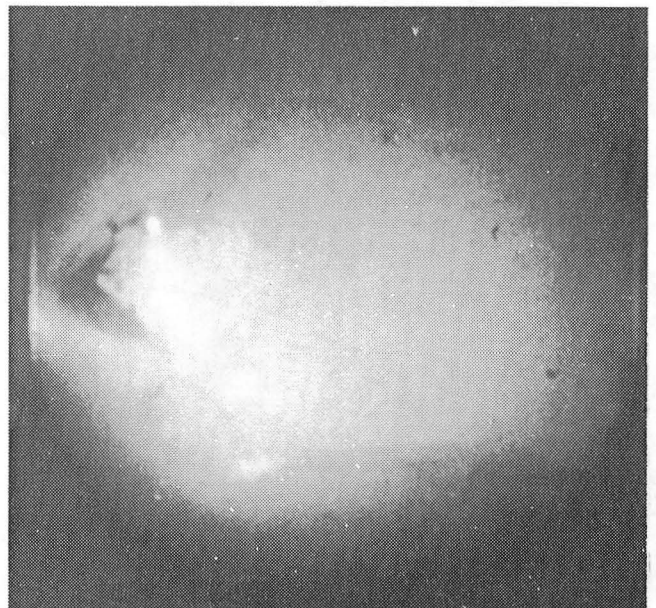
(a) Frame 1 of 4.



(b) Frame 2 of 4.



(c) Frame 3 of 4.



(d) Frame 4 of 4.

Figure 147. - Strike 136, Flight 82-044, aft camera.

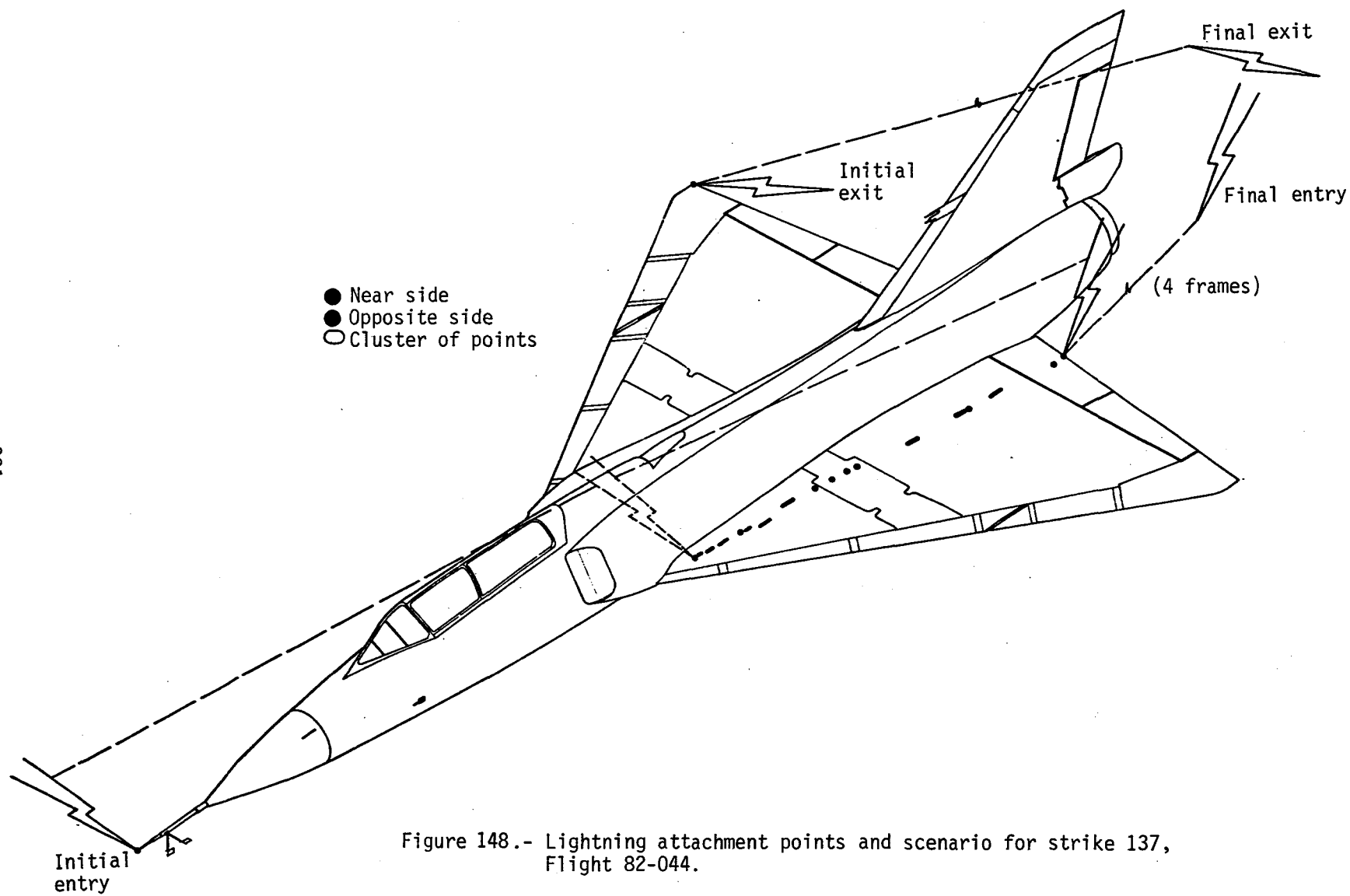


Figure 148.- Lightning attachment points and scenario for strike 137, Flight 82-044.

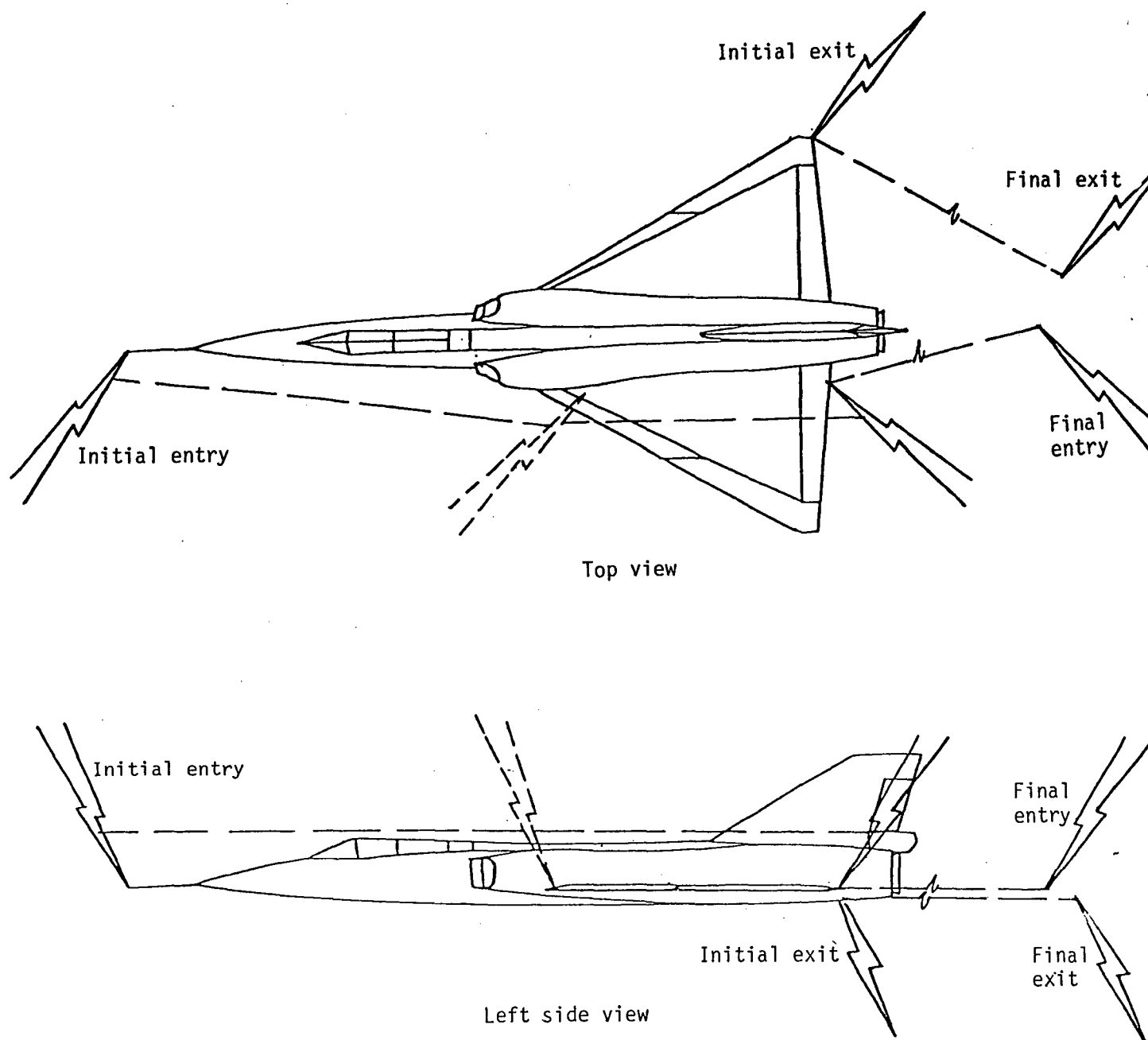
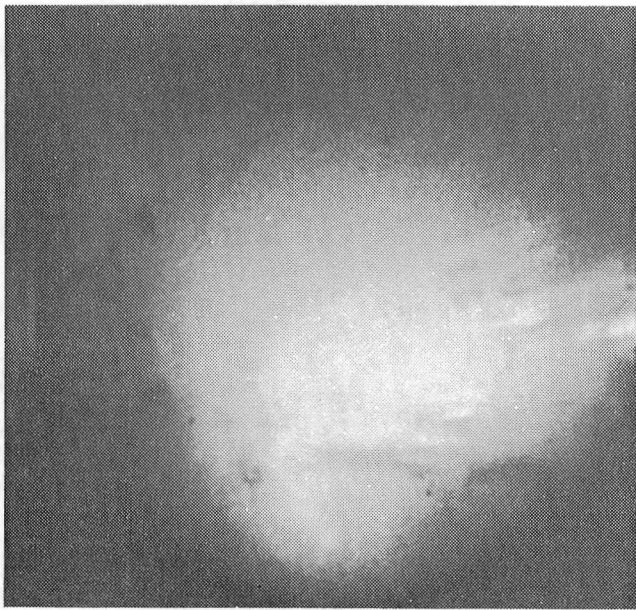


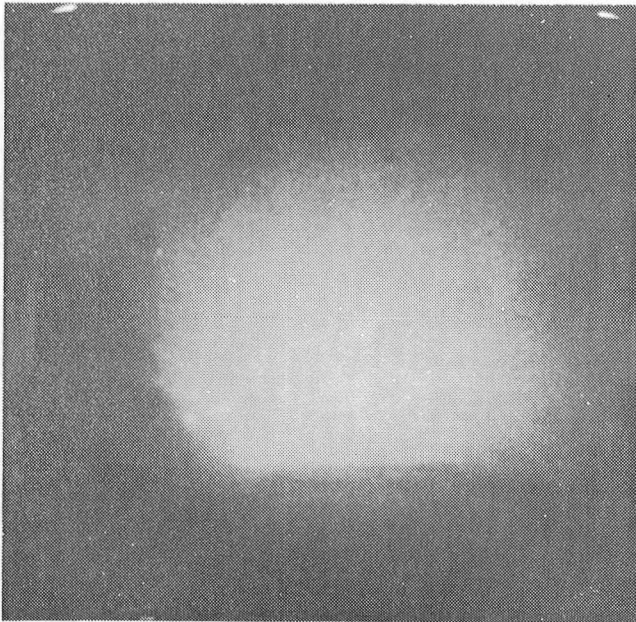
Figure 149.- Lightning attachment point scenario for strike 137, Flight 82-044.



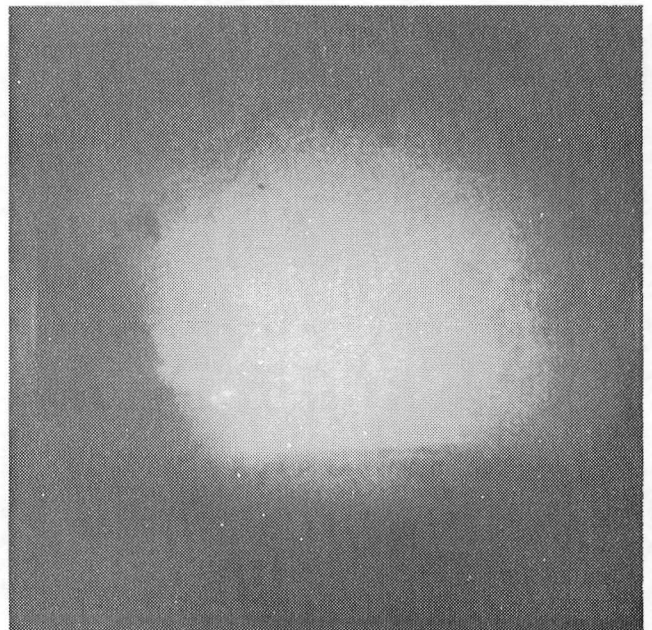
(a) Frame 1 of 4.



(b) Frame 2 of 4.

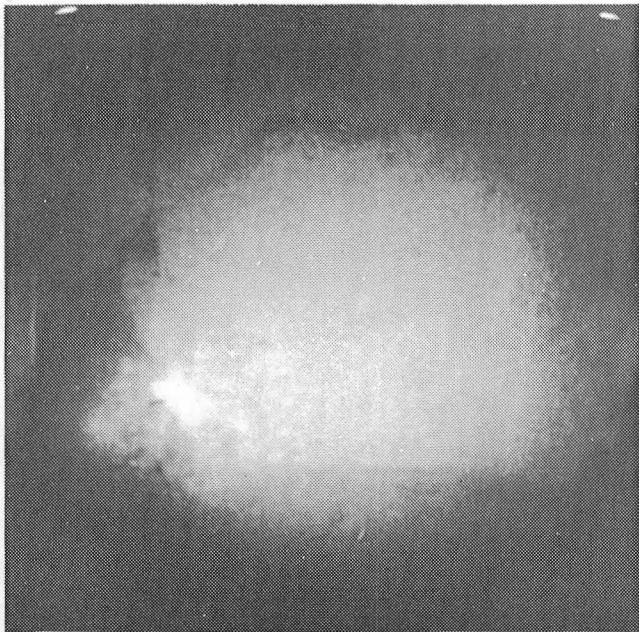


(c) Frame 3 of 4.

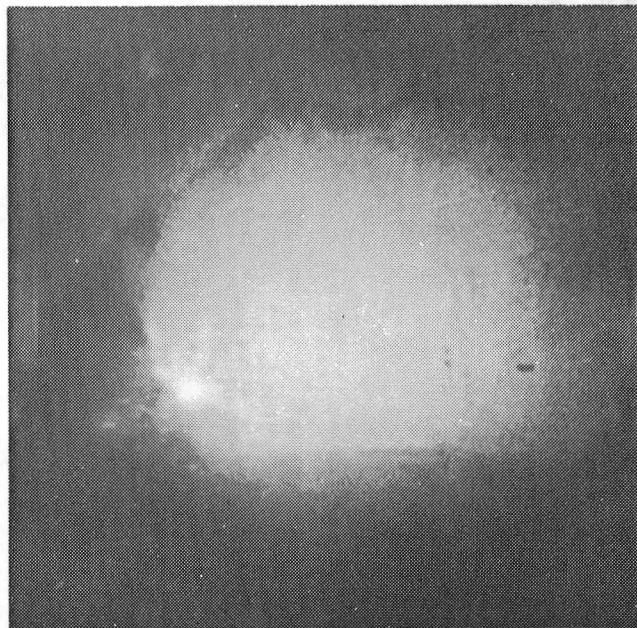


(d) Frame 4 of 4.

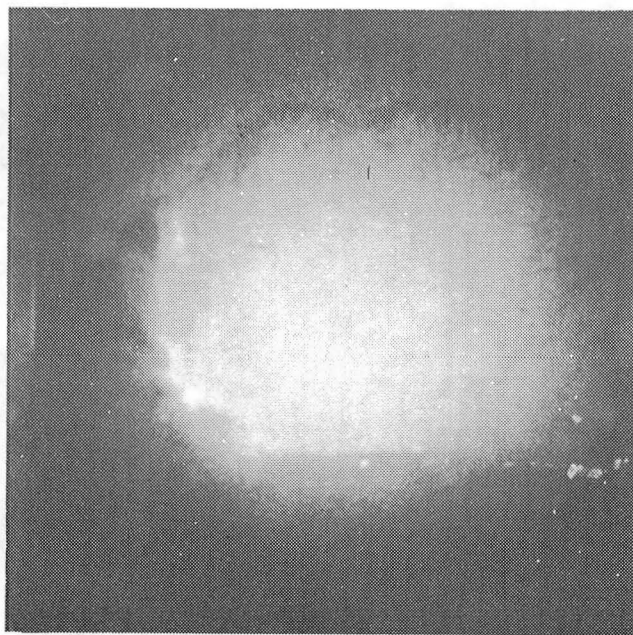
Figure 150. - Strike 137, Flight 82-044, aft camera.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 151. - Strike 138, Flight 82-044, aft camera.

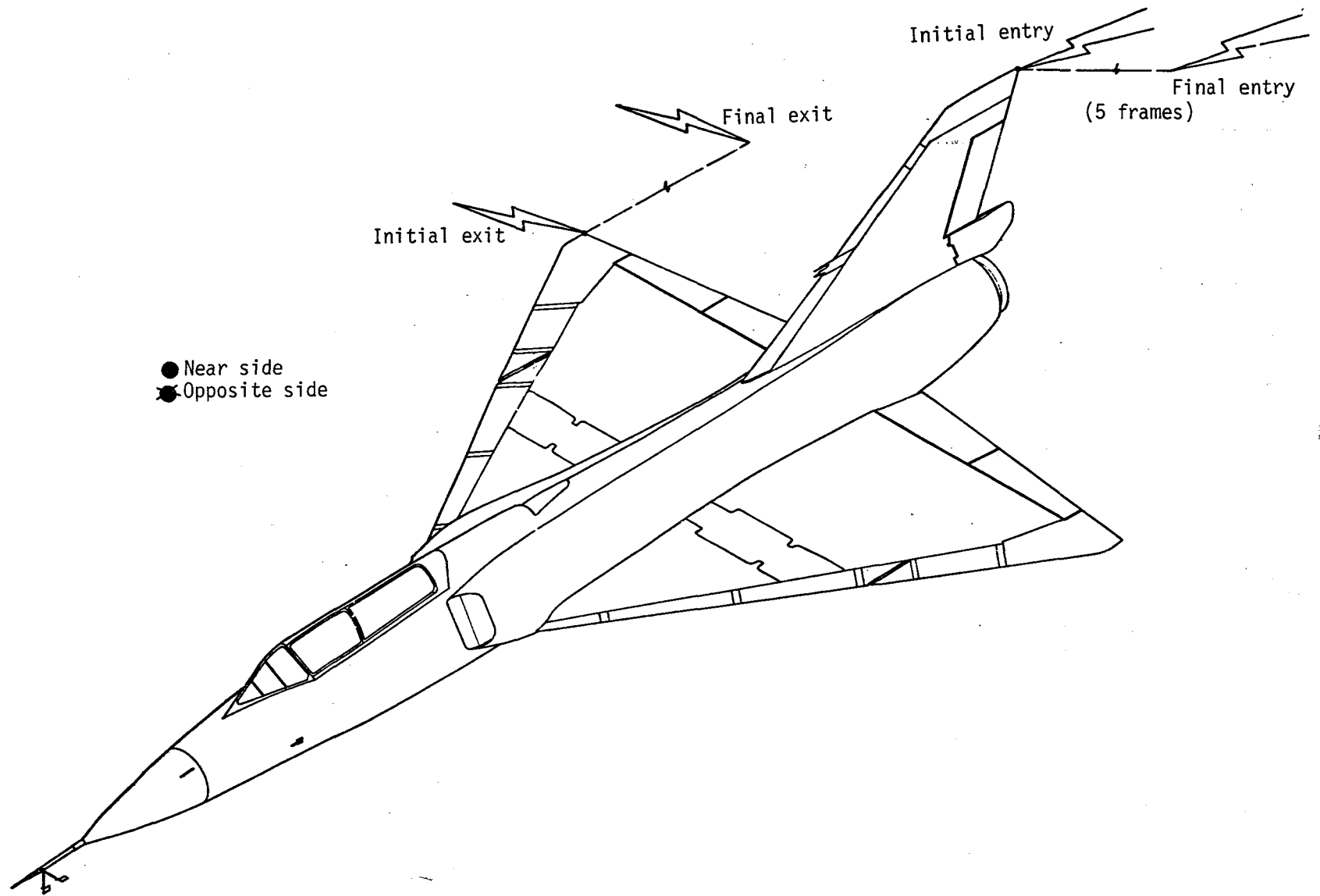


Figure 152.- Lightning attachment points and scenario for strike 139, Flight 82-044.

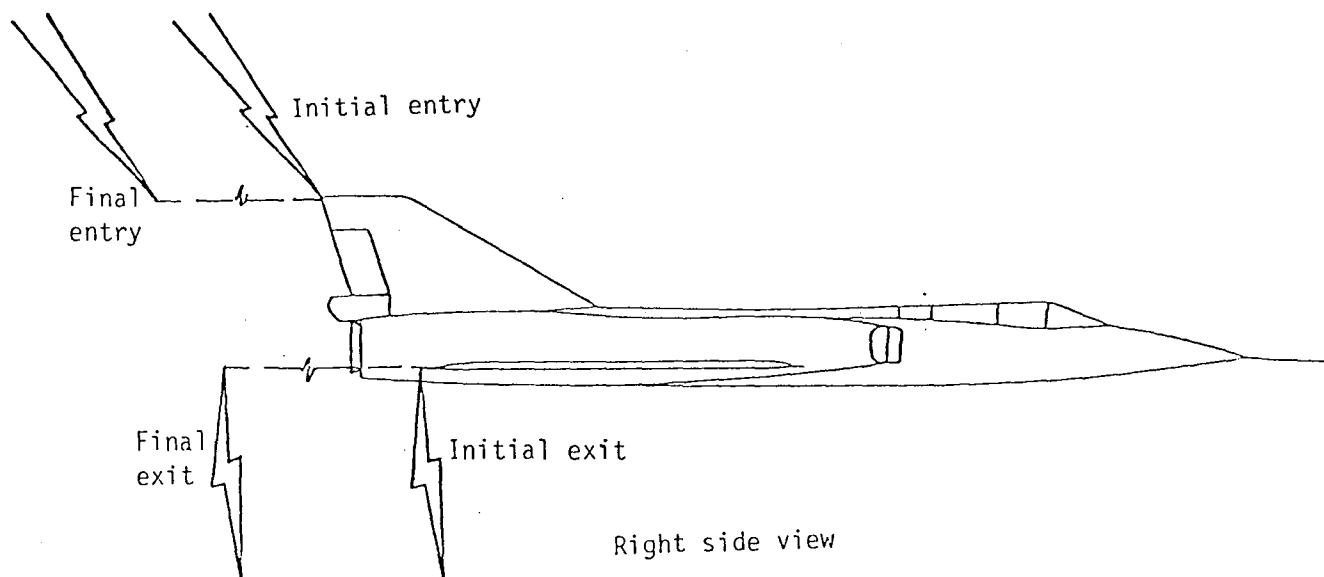
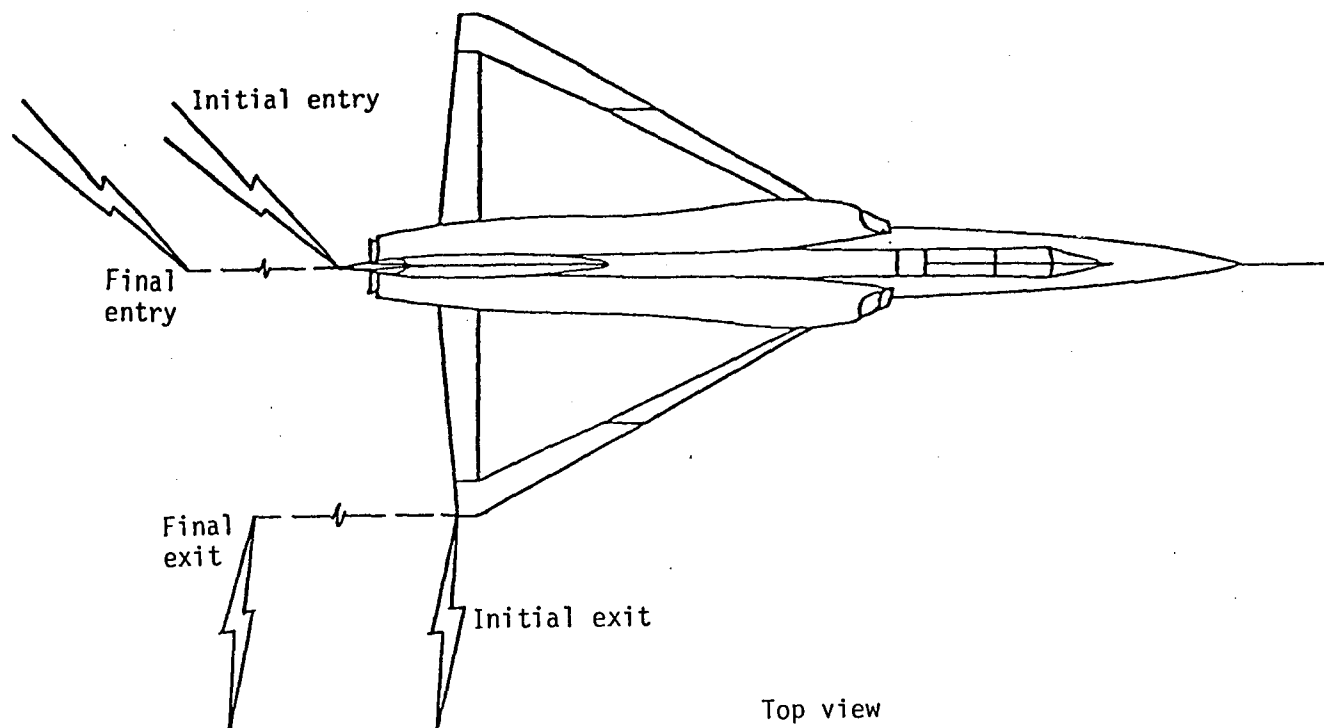
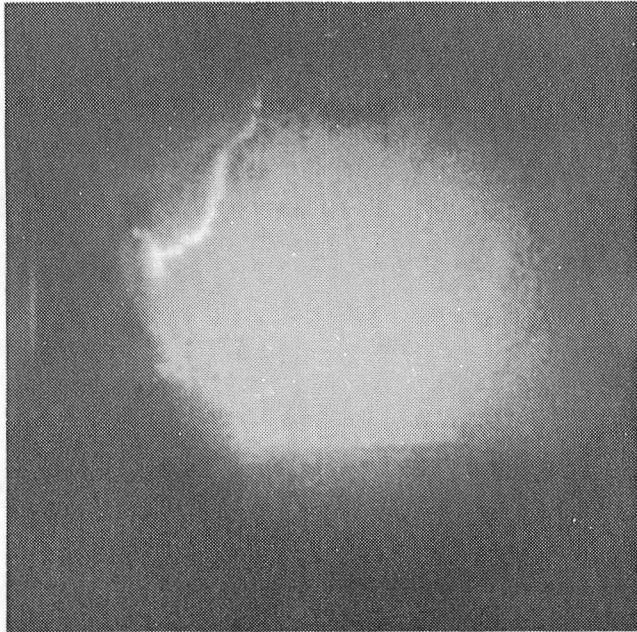
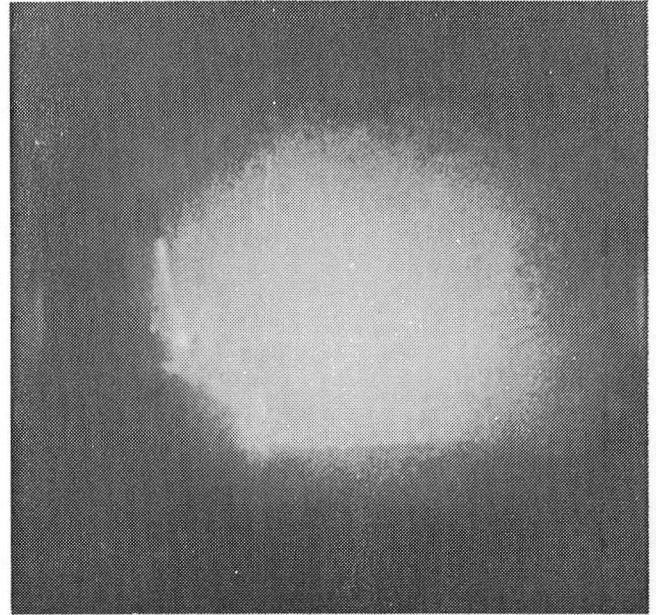


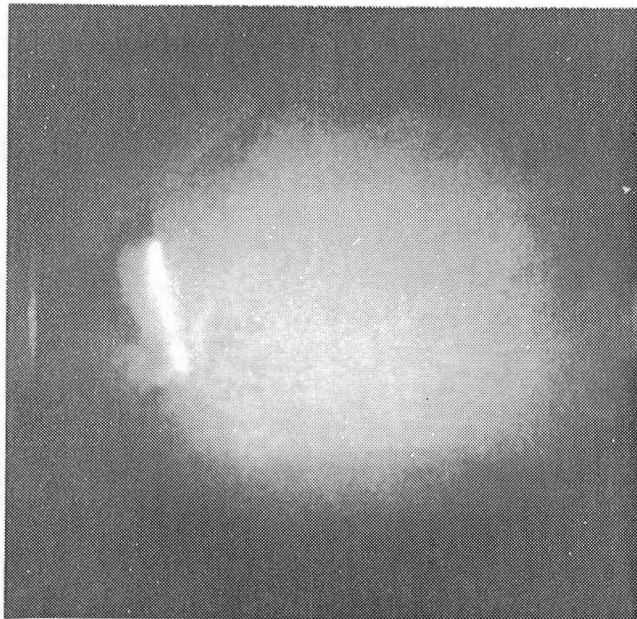
Figure 153.- Lightning attachment point scenario for strike 139, Flight 82-044.



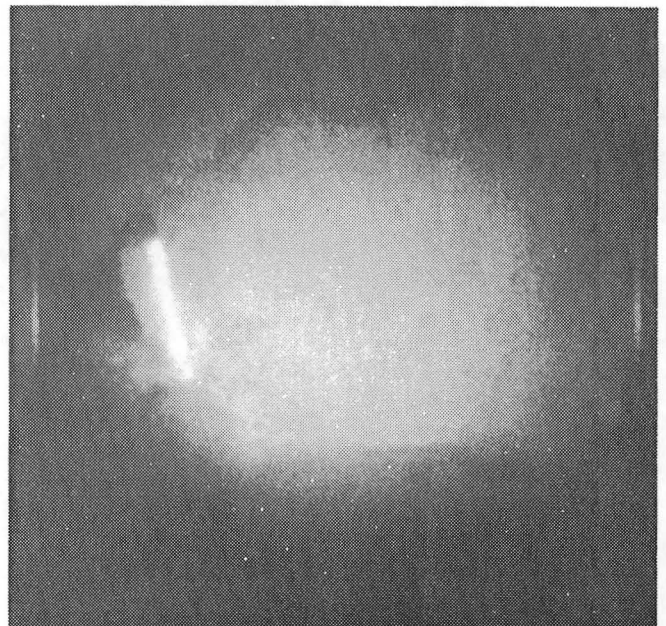
(a) Frame 1 of 5.



(b) Frame 2 of 5.

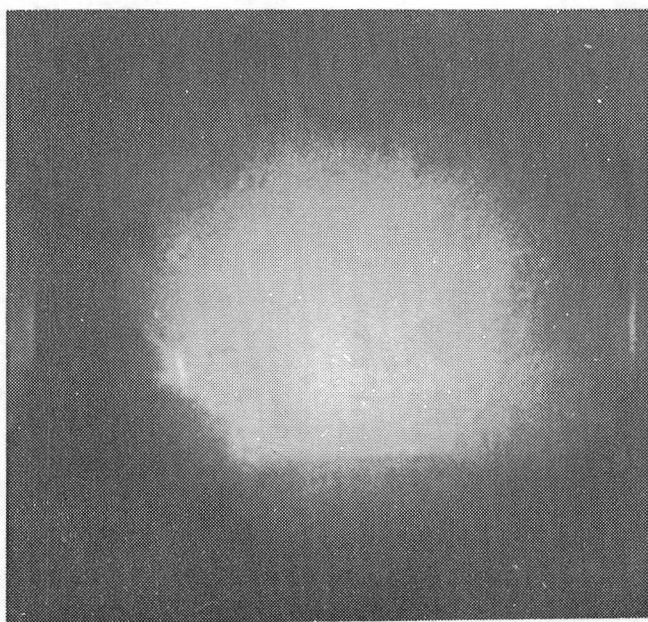


(c) Frame 3 of 5.



(d) Frame 4 of 5.

Figure 154. - Strike 139, Flight 82-044, aft camera.



(e) Frame 5 of 5.

Figure 154. - Concluded.

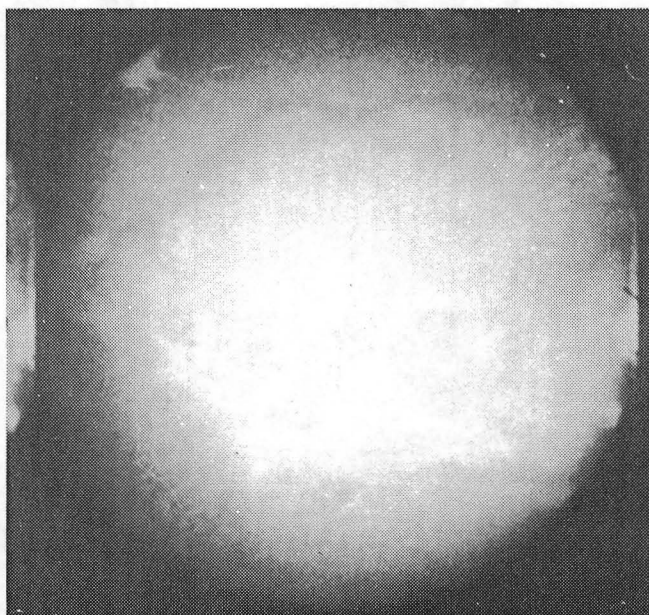
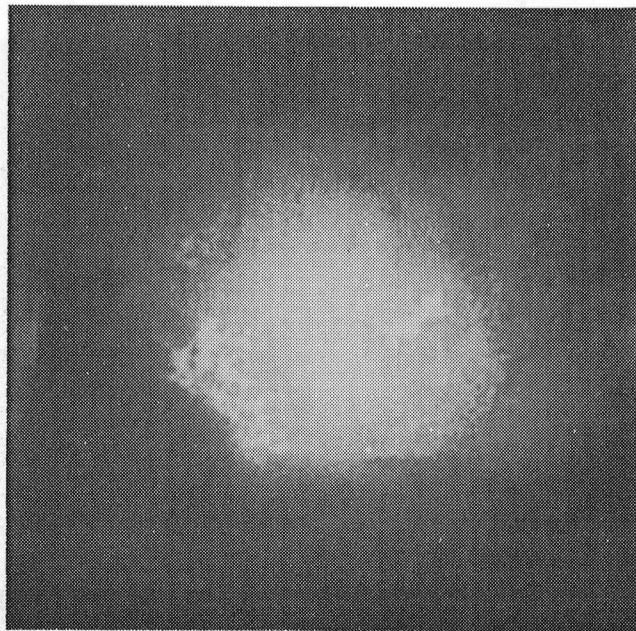
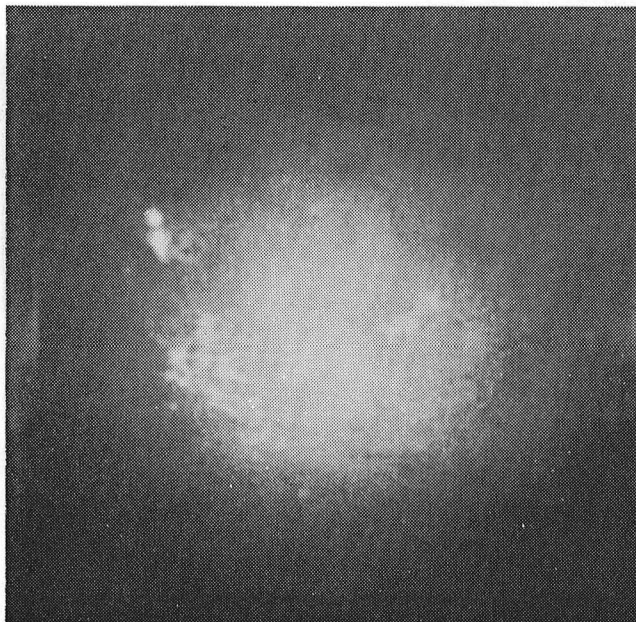


Figure 155. - Strike 140, Flight 82-044, aft camera.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 156. - Strike 143, Flight 82-044, aft camera.

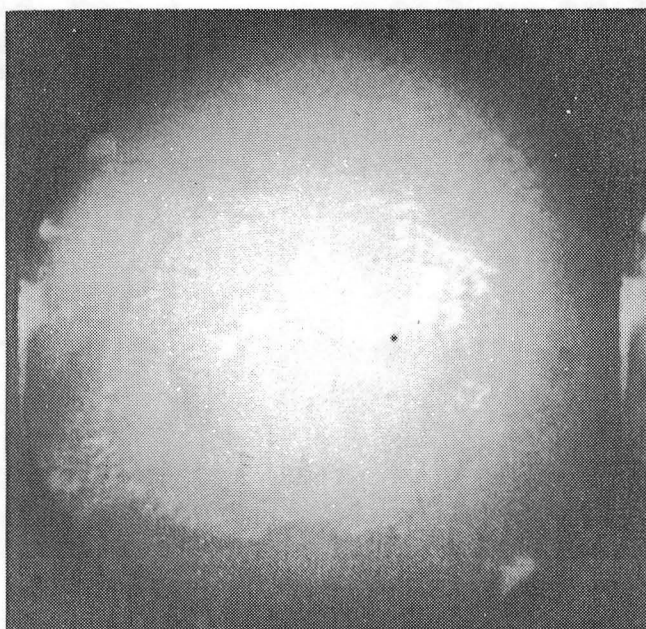
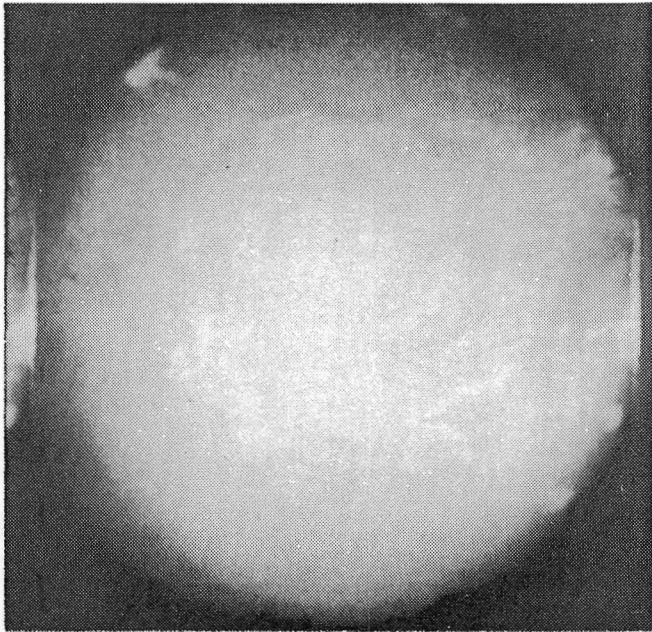
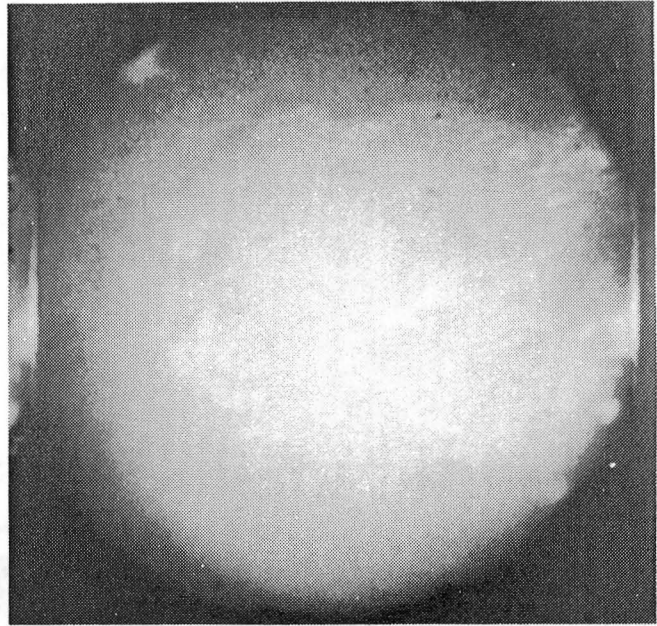


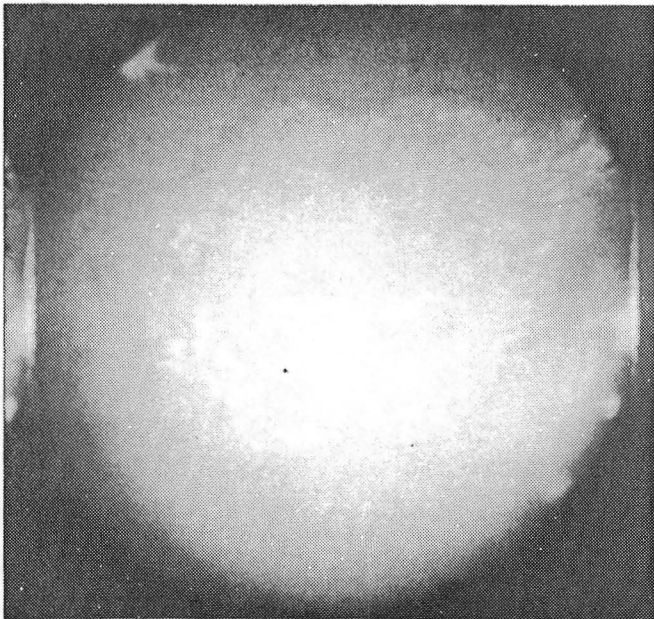
Figure 157. - Strike 145, Flight 82-044, aft camera.



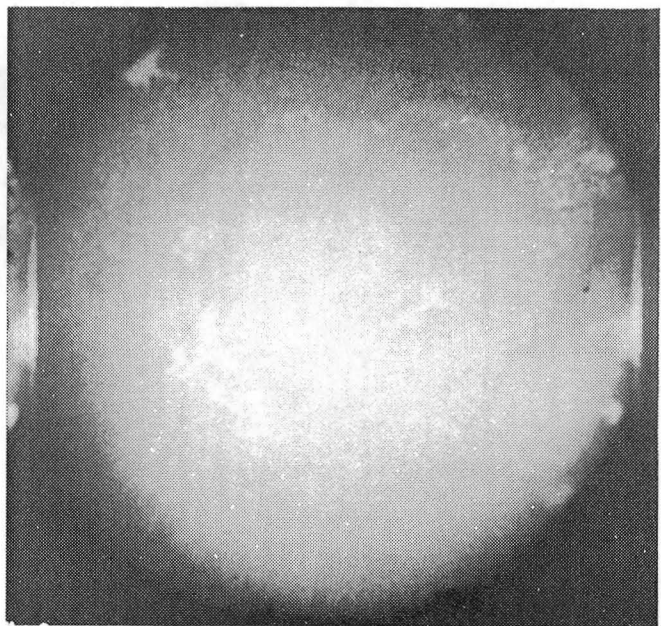
(a) Frame 1 of 5.



(b) Frame 2 of 5.

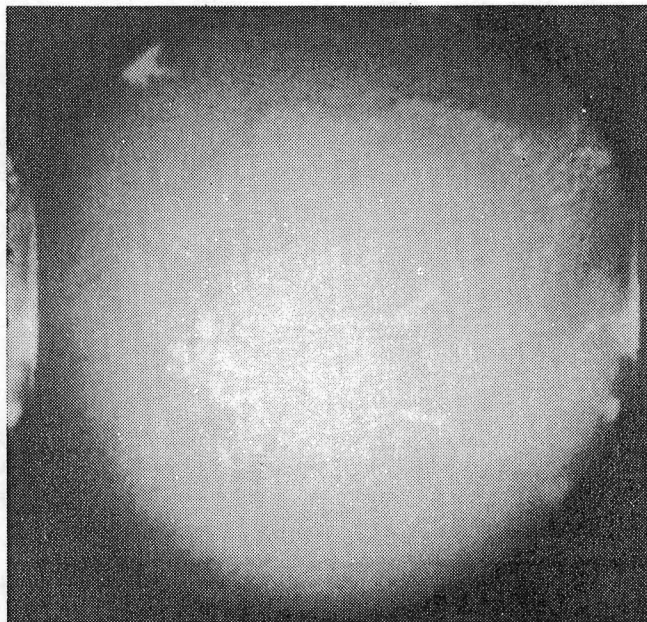


(c) Frame 3 of 5.



(d) Frame 4 of 5.

Figure 158. - Strike 146, Flight 82-044, aft camera.



(e) Frame 5 of 5.

Figure 158. - Concluded.

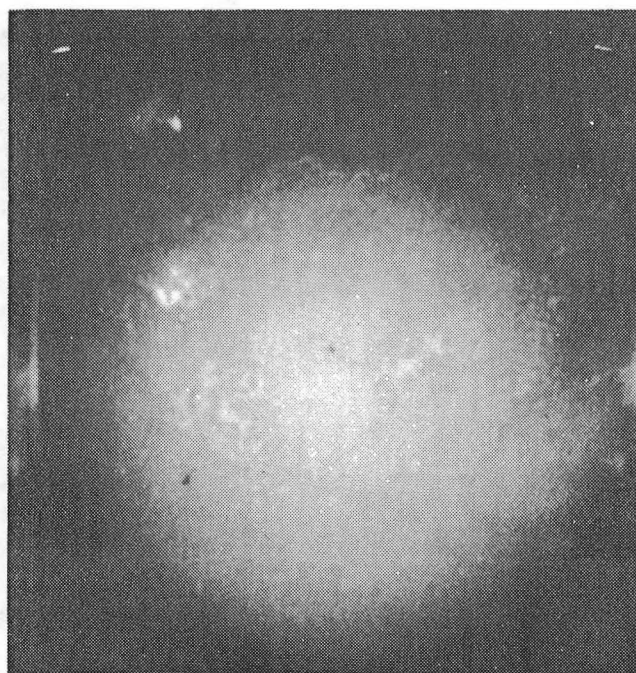


Figure 159. - Strike 148, Flight 82-044, aft camera.

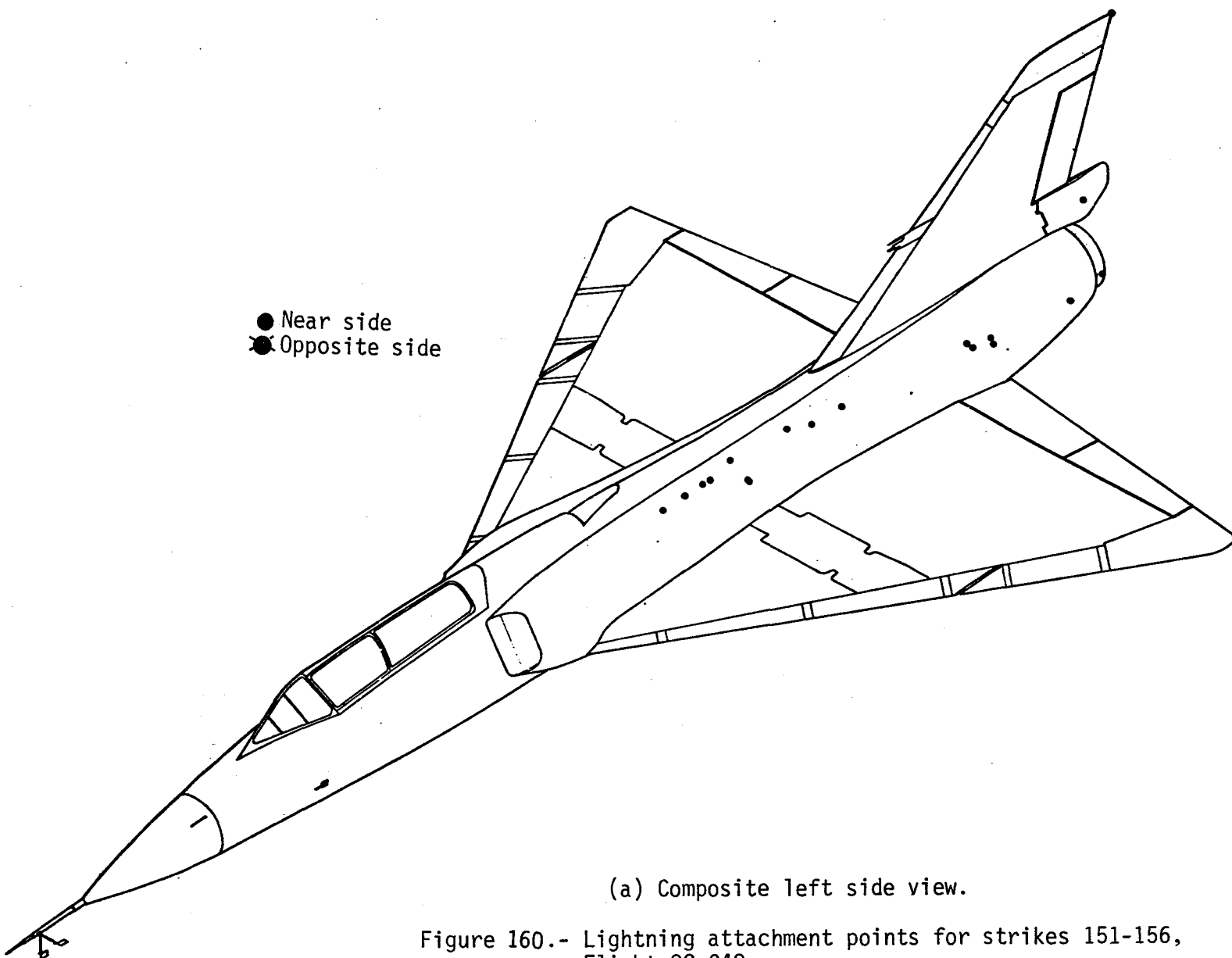
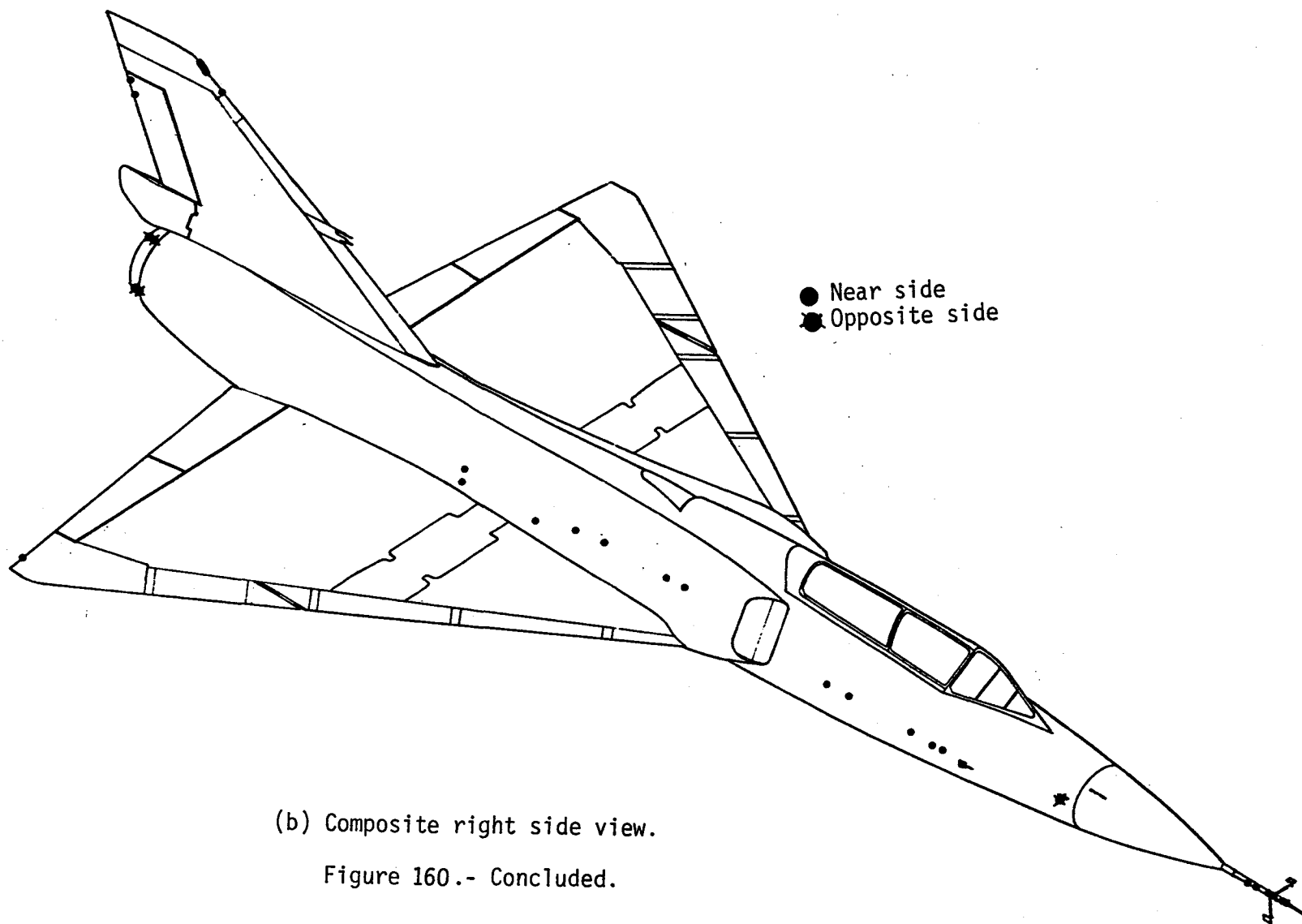
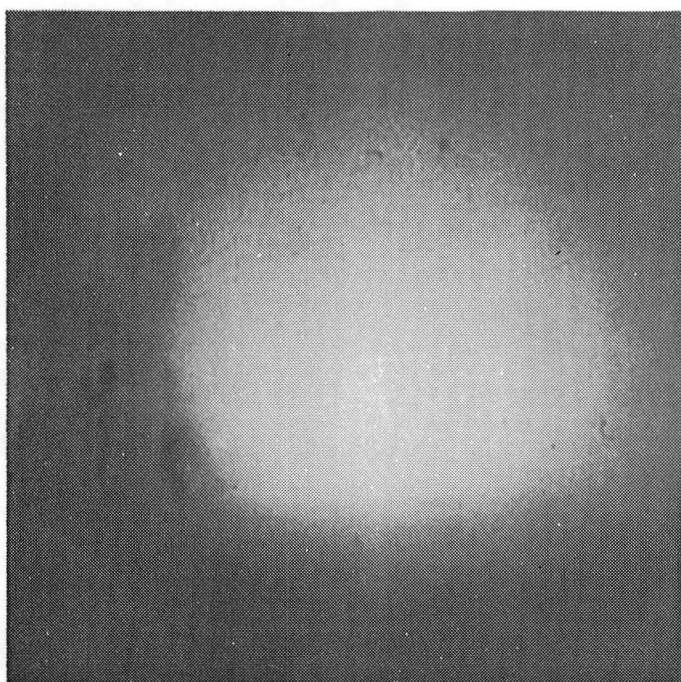


Figure 160.- Lightning attachment points for strikes 151-156,
Flight 82-048.

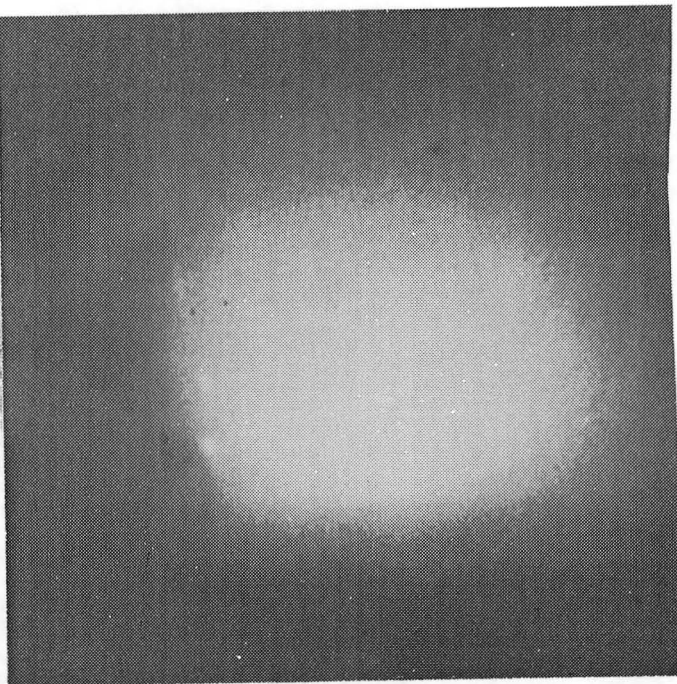


(b) Composite right side view.

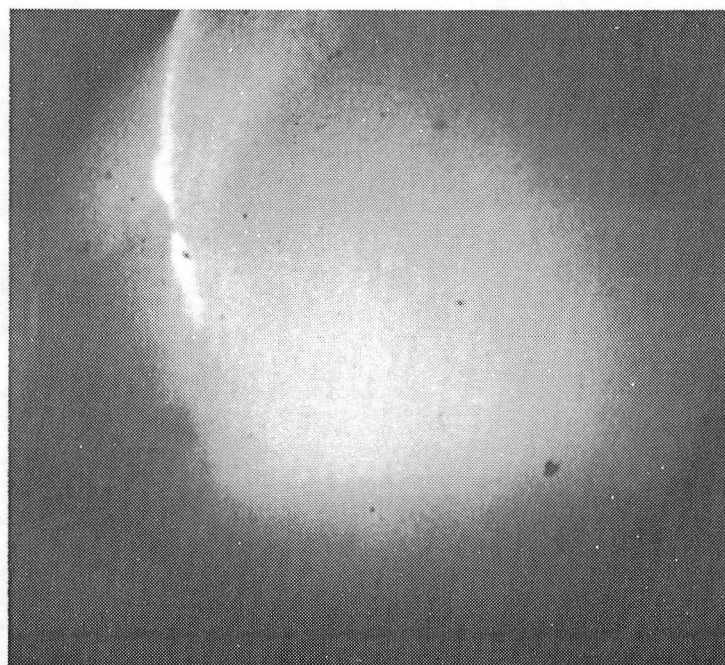
Figure 160.- Concluded.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 161. - Strike 152, Flight 82-048, aft camera.

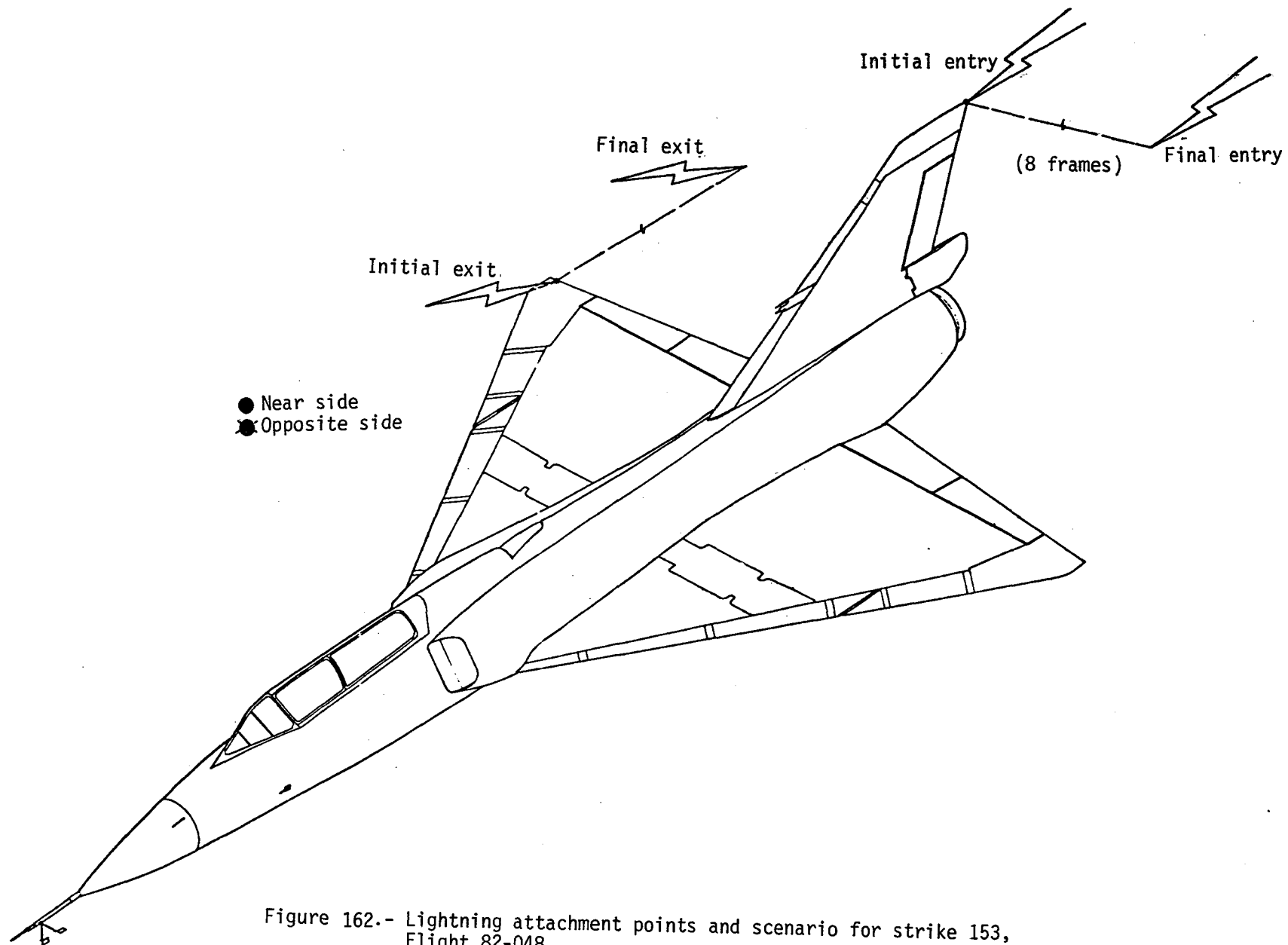


Figure 162.- Lightning attachment points and scenario for strike 153, Flight 82-048.

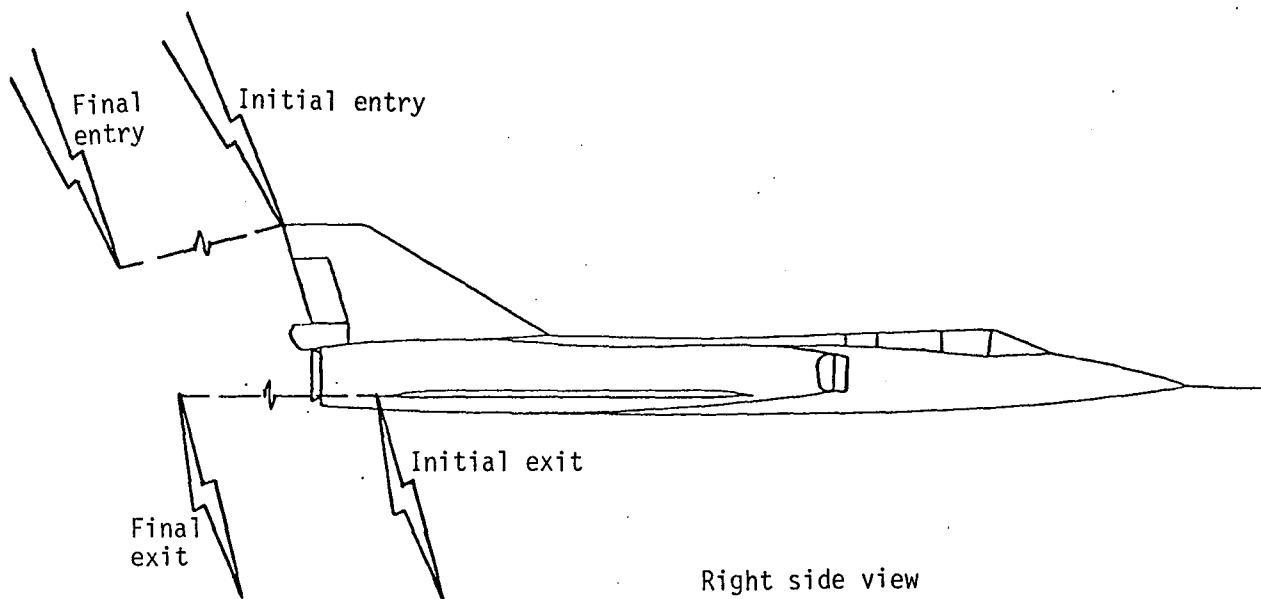
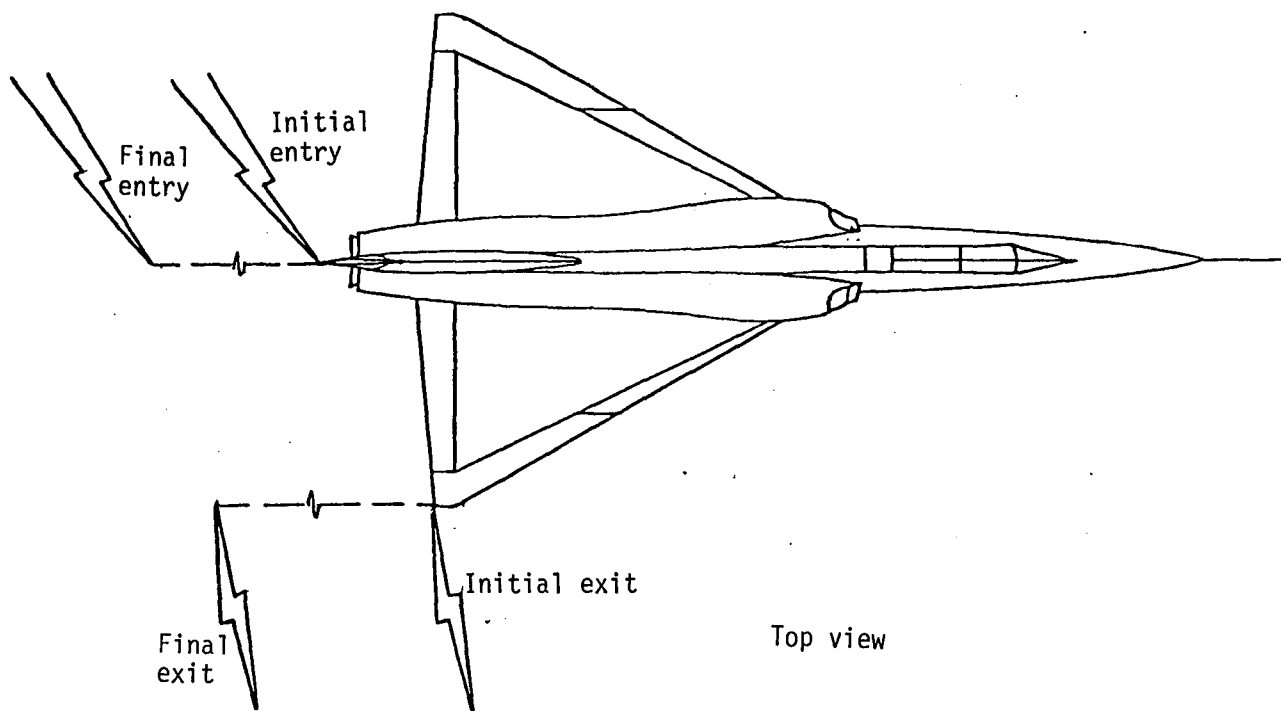
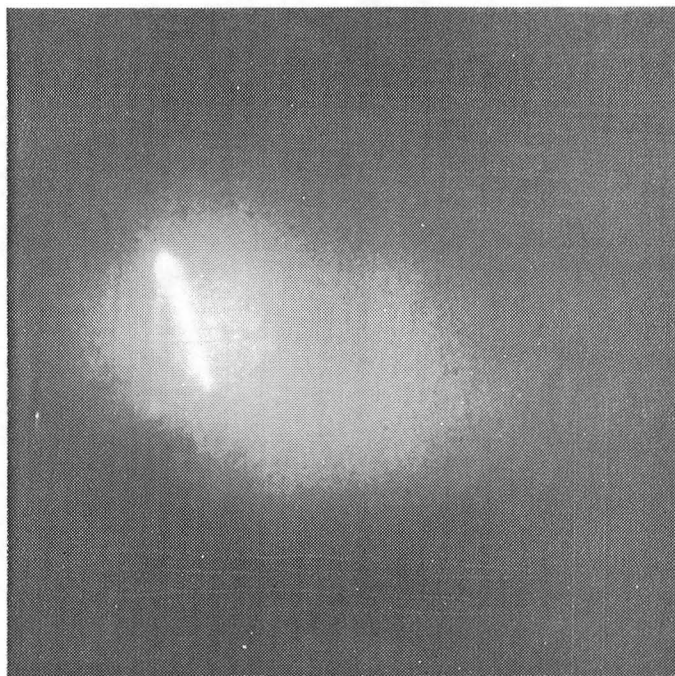


Figure 163.- Lightning attachment point scenario for strike 153, Flight 82-048.



(a) Frame 1 of 8.



(b) Frame 2 of 8.



(c) Frame 3 of 8.

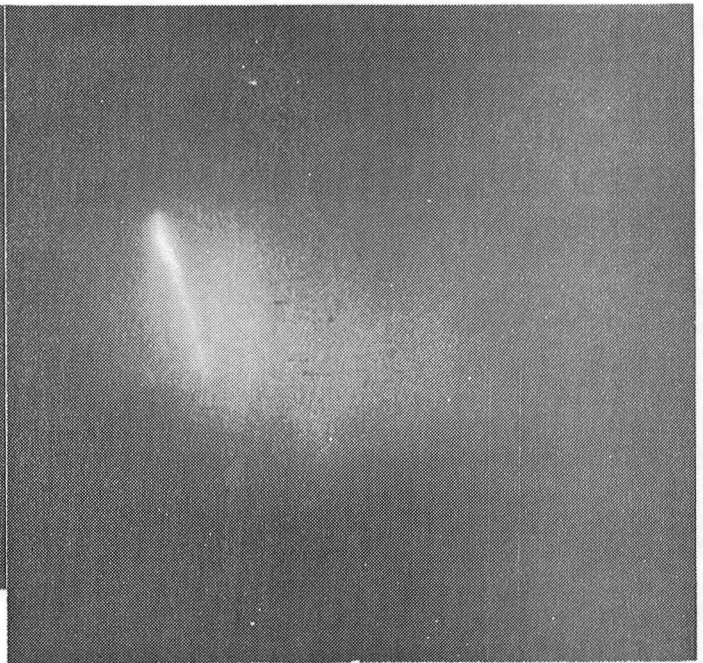


(d) Frame 4 of 8.

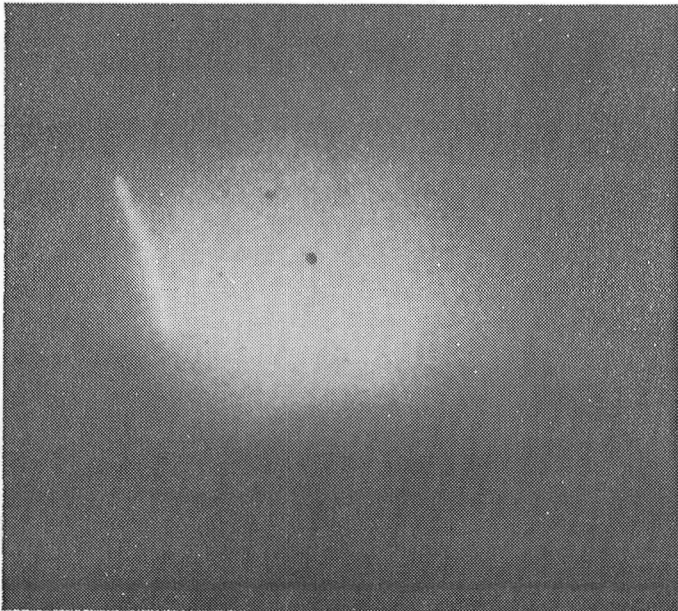
Figure 164. - Strike 153, Flight 82-048, aft camera.



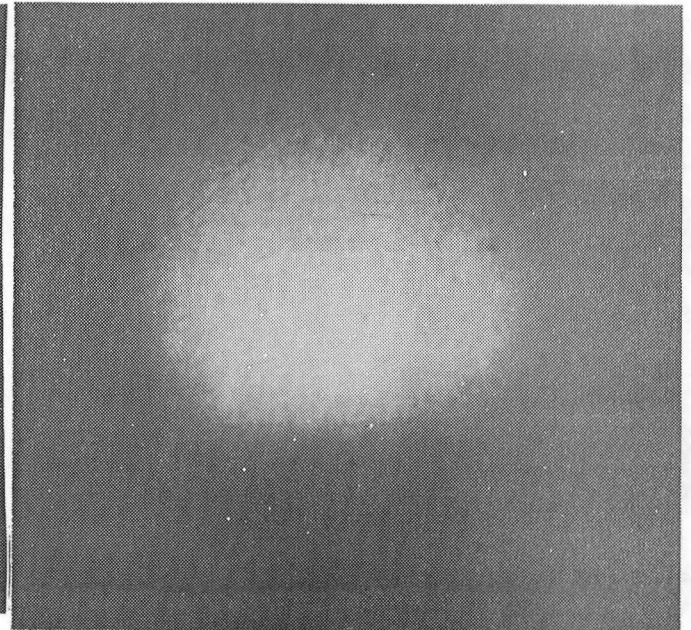
(e) Frame 5 of 8.



(f) Frame 6 of 8.



(g) Frame 7 of 8.



(h) Frame 8 of 8.

Figure 164. - Concluded.

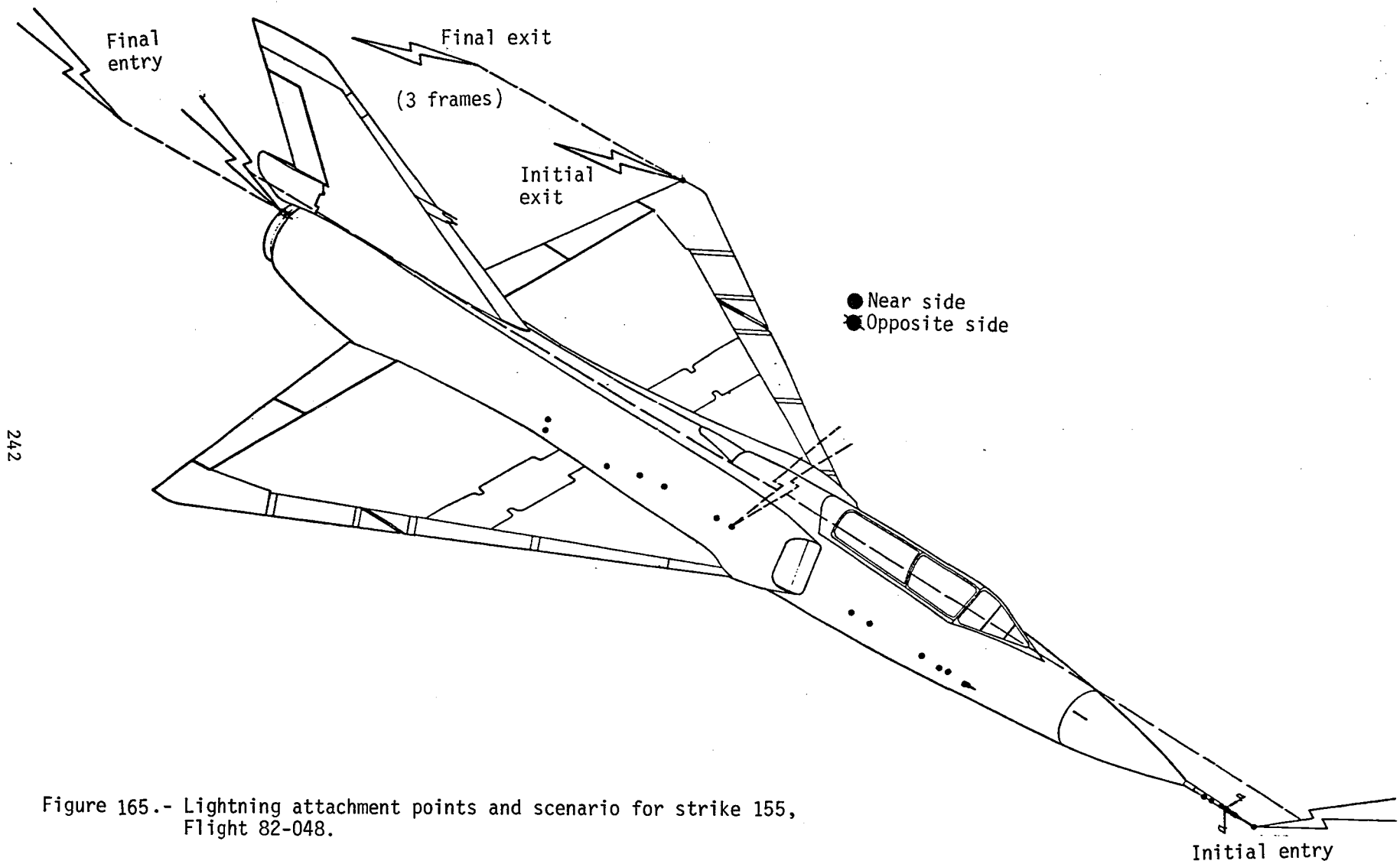


Figure 165.- Lightning attachment points and scenario for strike 155, Flight 82-048.

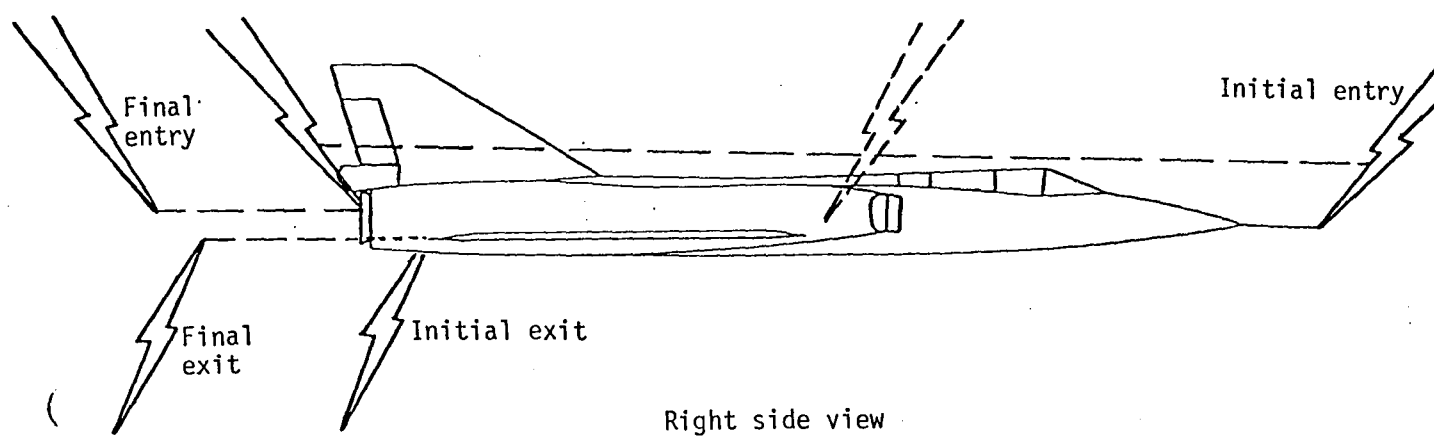
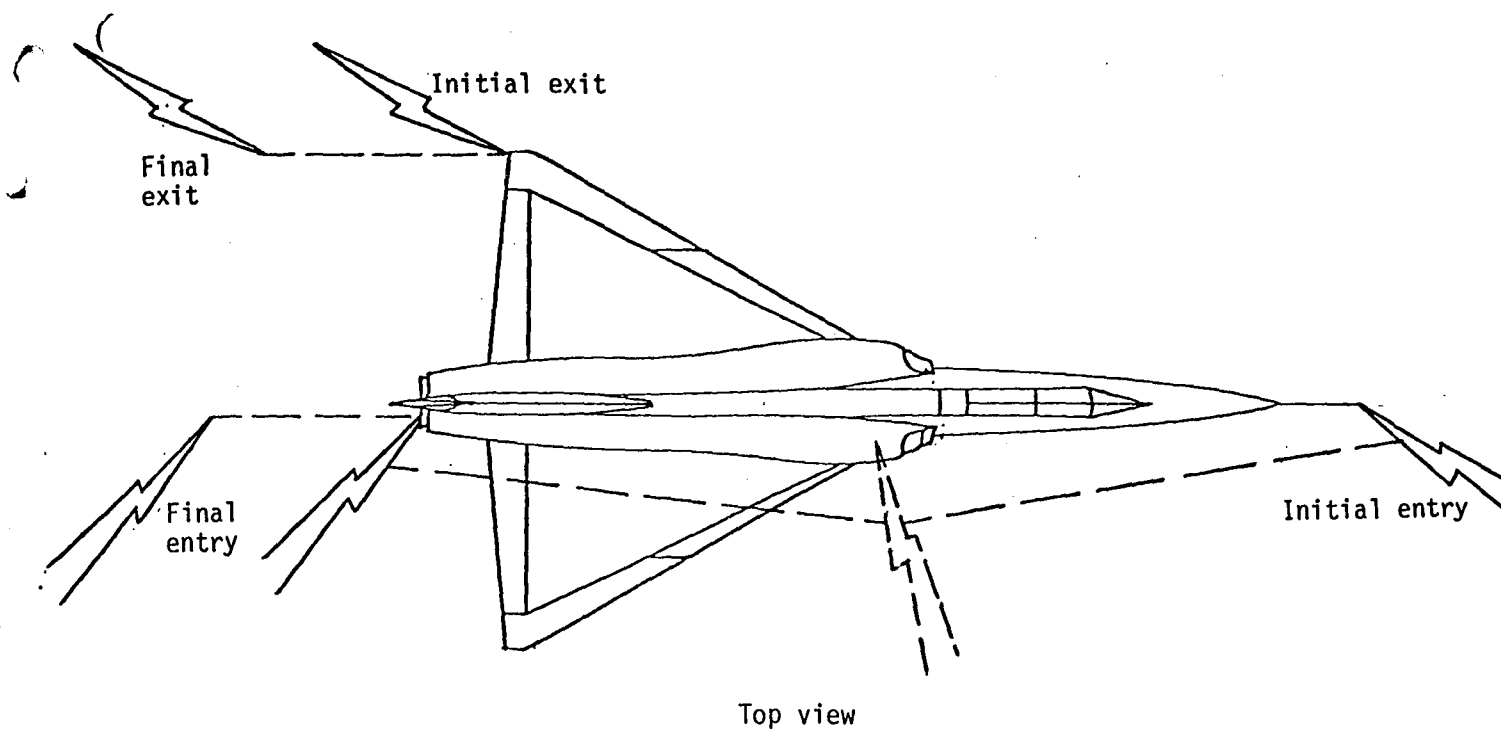
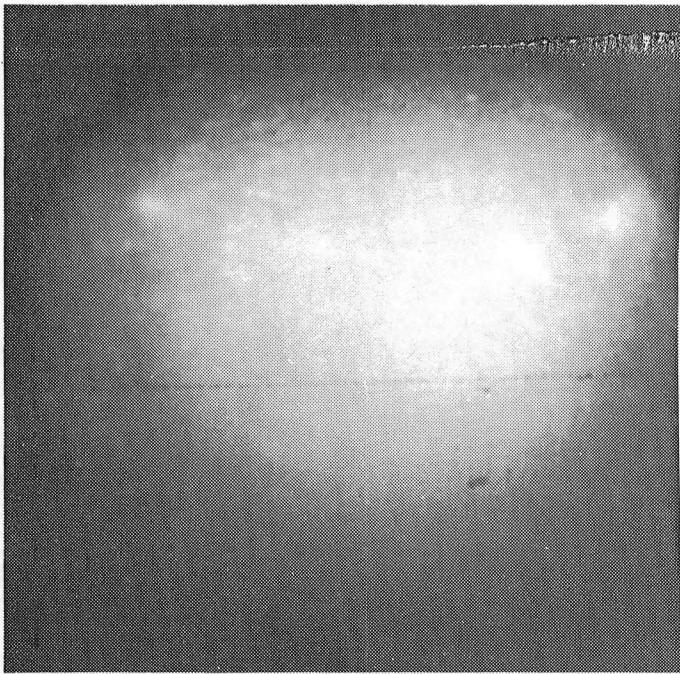
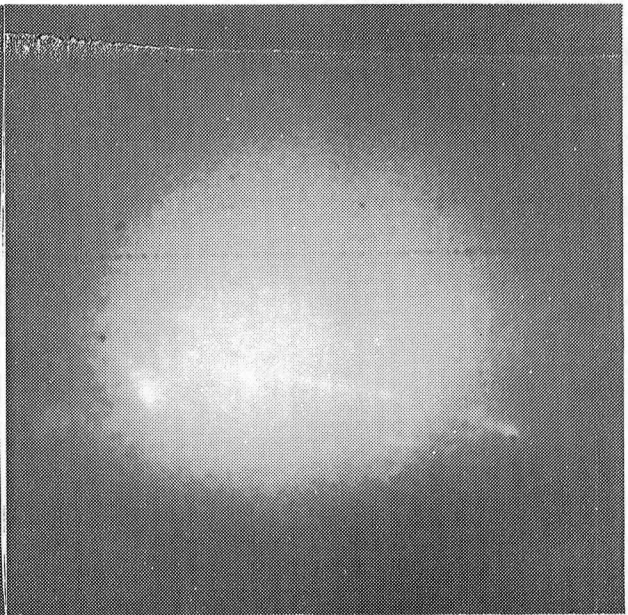


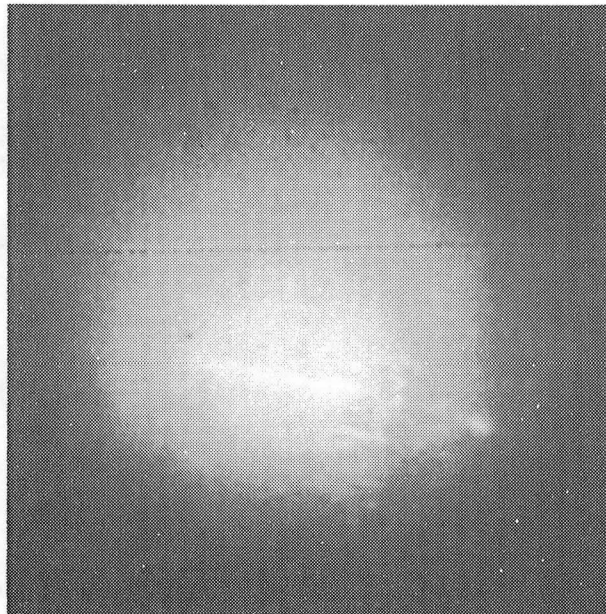
Figure 166.- Lightning attachment point scenario for strike 155, Flight 82-048.



(a) Frame 1 of 3.



(b) Frame 2 of 3.



(c) Frame 3 of 3.

Figure 167. - Strike 155, Flight 82-048, aft camera.

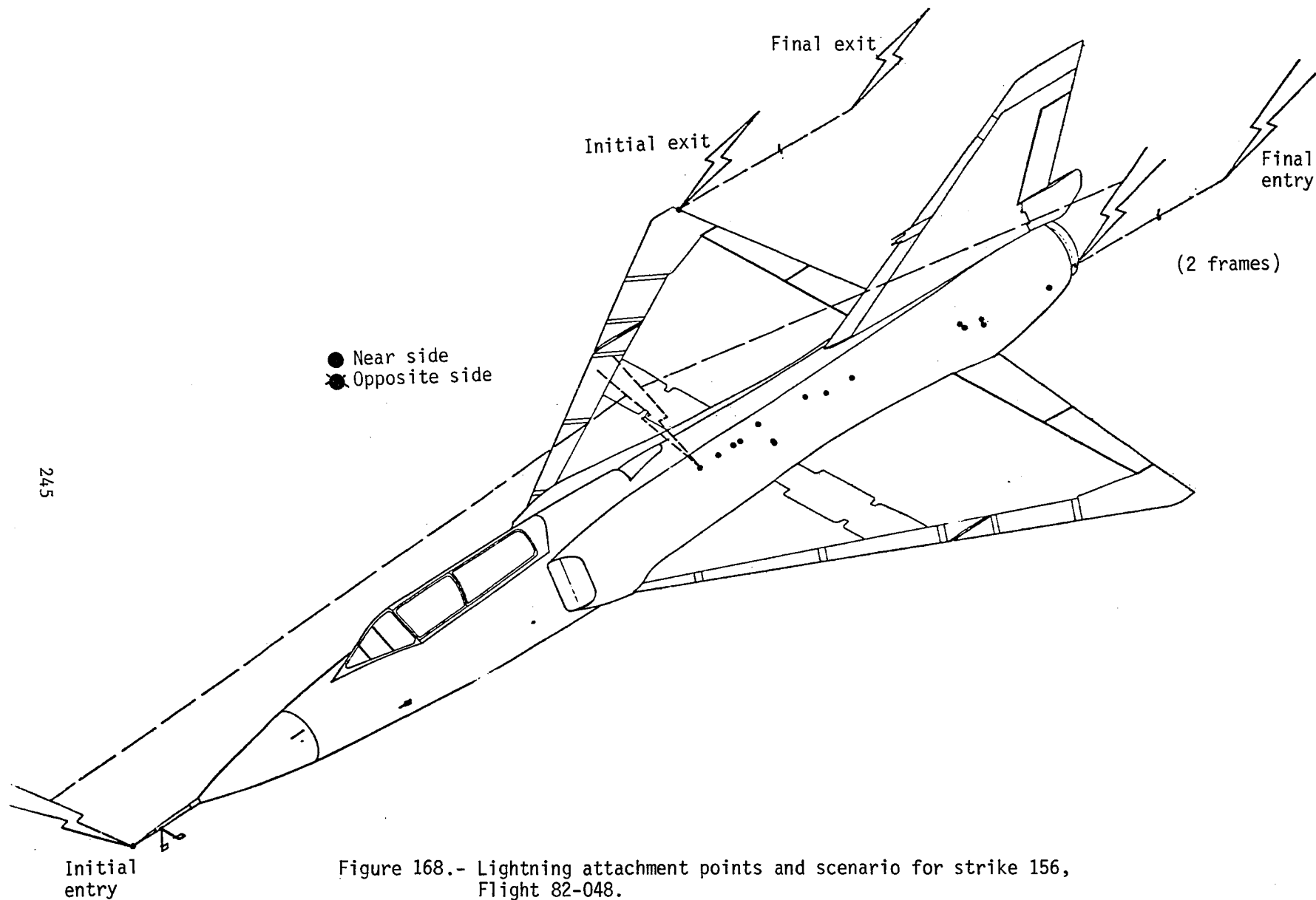
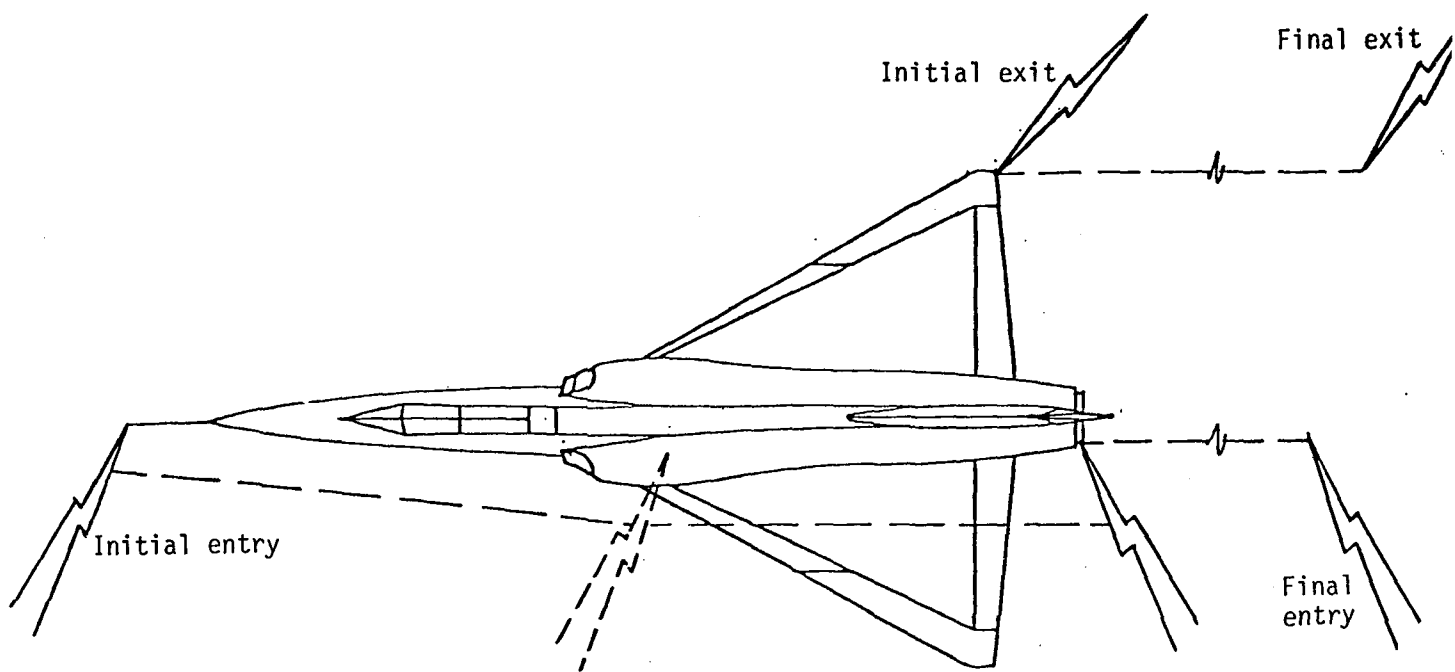
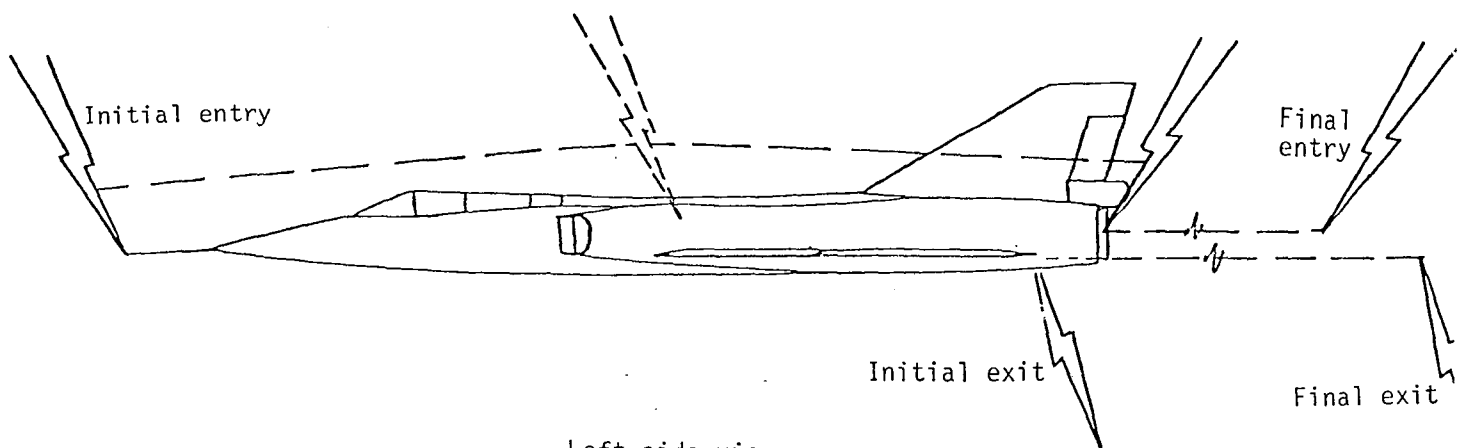


Figure 168.- Lightning attachment points and scenario for strike 156, Flight 82-048.

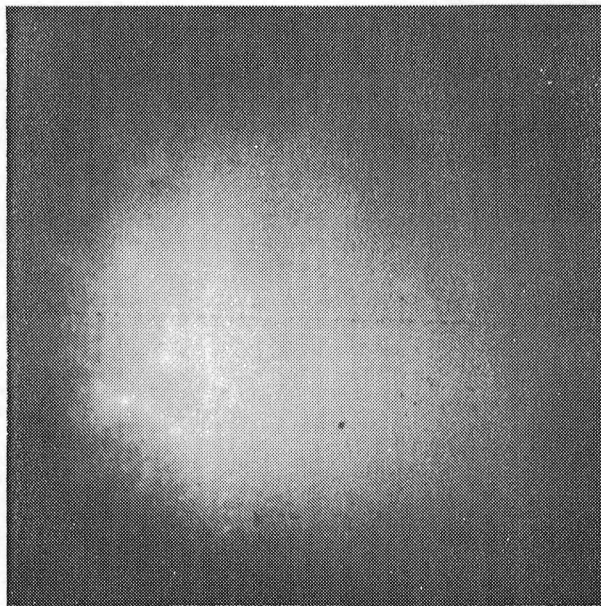


Top view

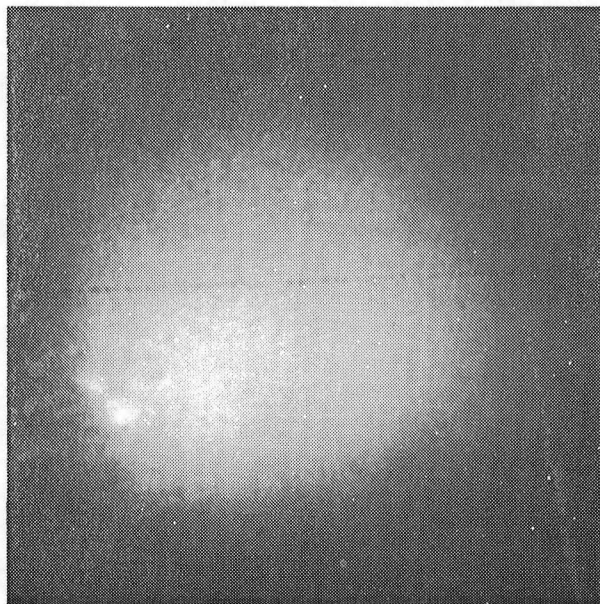


Left side view

Figure 169.- Lightning attachment point scenario for strike 156,
Flight 82-048.



(a) Frame 1 of 2.



(b) Frame 2 of 2.

Figure 170. - Strike 156, Flight 82-048, aft camera.

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16. Abstract As part of the NASA Langley Research Center Storm Hazards Program, 241 thunderstorm penetrations were made in 1982 with an F-106B airplane in order to record direct-strike lightning data and the associated flight conditions. During these penetrations, the airplane received 156 direct lightning strikes; in addition, lightning transient data were recorded from 26 nearby lightning flashes. The tests were conducted within 150 nautical miles of Hampton, Virginia, assisted by ground-based weather-radar guidance from the NASA Wallops Flight Facility. This report presents the photographs of the lightning attachments taken from two onboard 16-mm color movie cameras and the associated strike attachment patterns. The paper also includes a table of the flight conditions recorded at the time of each lightning event, and a table in which the data in this paper are cross-referenced with the previously published lightning electromagnetic waveform data.					
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